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AN APPLICATION OF MARGINAL  
ANALYSIS TO BASE LEVEL SELF-  
SUFFICIENCY KIT CONSTRUCTION.

THESIS

AFIT/GOR/SM/78D-3

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Timothy R. Bridges  
Captain USAF

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AN APPLICATION OF MARGINAL  
ANALYSIS TO BASE LEVEL SELF-  
SUFFICIENCY KIT CONSTRUCTION

THESIS

Presented to the Faculty of the School of Engineering  
of the Air Force Institute of Technology  
Air Training Command  
in Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science

by

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Graduate Operations Research

December 1978

Approved for public release; distribution unlimited

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Last and not least, my family has helped me maintain

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Timothy R. Bridges

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## Abstract

This thesis develops and demonstrates a method for improving the construction of Base Level Self-Sufficiency (BLSS) kits. This is accomplished by utilizing a cumulative density function describing the probability of Y or fewer downed aircraft. This density function is used in an application of marginal analysis in the construction of demonstration BLSS kits. A comparison is then made between the present, proposed, minimization of expected backorders, and the researcher's methodology to determine the best. In all cases, the researcher's method is shown to have a higher probability of Y or fewer grounded aircraft for the particular Y value of interest. The system under which the BLSS must operate is modeled using the DYNAMO system language so as to ascertain the effects upon BLSS performance with parameter changes.



AN APPLICATION OF MARGINAL ANALYSIS  
TO BASE LEVEL SELF-SUFFICIENCY  
KIT CONSTRUCTION

I. Introduction

All Air Force flying units have a wartime mission which requires them to either deploy to other bases close to the possible front line areas throughout the world or to fight in place. In order to meet the increased spare parts requirements due to higher wartime flying rates, spare part kits are constructed and maintained. There are two types of kits: one for the unit which would deploy and another for the unit which would remain on station. Both kits are part of the War Reserve Material Program. The War Readiness Spares Kit (WRSK), sometimes referred to as the "flyaway kit," is defined as

... an air transportable package of War Reserve Material (WRM) spares, repair parts, and related maintenance supplies required to support planned wartime or contingency operations of a weapon or support system for a specified period of time pending resupply (Ref 1:3).

Some WRSK kits are prepositioned at predetermined deployment areas; however, the majority of them are flown via airlift aircraft which accompany the deploying unit. There are, as a consequence, certain limitations on the WRSK kit such as the dollar value of investment, the volume, and

the weight.

The other WRM kit is the Base Level Self-Sufficiency (BLSS) kit which is always at the home station. Because of this, BLSS kits are not restricted by weight or volume, within reason, as are the WRSK kits. The only restriction on the BLSS kit is the budget. The BLSS kit is defined as

WRM spares and repair parts intended for use as base support for units which plan to operate in place during wartime, considering the available maintenance capability (Ref 1:3).

The present methodologies for computing the contents of the two kits are different because the WRSK kit has received higher priority and research time in the past. Presently, the WRSK is computed using the D029 system. This system computes requirements using a non-probabilistic (conventional) methodology to get goals and then applies a technique to determine a better kit (meets or exceeds goals for same cost) or meets goals at less cost. The D029 system assumes a remove and replace maintenance concept. This is the one large difference between the WRSK and BLSS kit. A deployed unit with a WRSK would to one degree or another, suffer from a reduction in local repair capability. The BLSS kit, never moving from its normal repair facility, can utilize the remove, repair, and replace concept realistically. The present method for computing BLSS requirements is non-probabilistic and described in AFLC Regulation 57-18 (Ref 2: App I, 1).

### Statement of the Problem

The BLSS kit is now computed in a manner which does not seek to optimize the reparable assets in the BLSS kit.

The need for optimization was best stated by General F. Michael Rogers, former commander of the Air Force Logistics Command (AFLC) when he said that:

Computations of WRM levels are made to stock consumable supplies and spare parts required to carry on the planned wartime activity.... Funding deficits become the major constraining factor in our ability to surge.... With reduced dollars, we have been unable to buy WRM in sufficient amounts .... We want to squeeze every last measure of efficiency and effectiveness out of the resources that are provided (Ref 3:38-39).

Thus, this thesis will attempt to apply an optimization technique to the construction of the BLSS kit.

### Objectives

1. Statistically describe the cumulative density function for the number of aircraft grounded due to supply.
2. Present a method of optimizing kit construction and factor presentation for ease of managerial decision making.

## II. Background

### Introduction

There are two basic types of items in the Air Force supply system; consumables and reparableables. Those items classified as consumables are replaced when they fail or are consumed, whichever occurs first. Consumables are never repaired. Reparables, on the other hand, are always repaired unless they are damaged beyond repair and are subsequently condemned. A new part is then procured through the procurement cycle in order to replace the condemnation. Consumables are replaced by using a economic order quantity (EOQ) policy which only procured when the inventory level reaches a reorder point. The reorder point is established at a level which will allow for the procurement delay and normal system demands prior to reaching a backorder condition. Backorders occur when there is a demand in excess of available replacements. In general, EOQ items are inexpensive; whereas reparable items, tend to be expensive and as of 1966, constituted 78% of the total Air Force investment in spares (Ref 4:1).

This chapter will consider the present Air Force inventory system and its implications on the BLSS kit. Additionally, discussions will include aircraft status and the supply system, reparable item levels, BLSS requirement generation, AFLC present computation methodology, METRIC, and other previously developed techniques and methodologies

for constructing WRM kits.

#### The Two Echelon Inventory System

Presently, the Air Force uses a two echelon inventory system (depot and base). Each base has its own inventory system and is fed by a depot which has its own system. The depot services many bases and handles most of the procuring for resupply.

When an item on an aircraft fails, it is removed and replaced with a serviceable item from the base stock if an item is available. One of two events then occurs with the failed part. It is either classified as Not Repairable This Station (NRTS) or it is repaired at the base. If it is repaired locally, the part is returned to the base stock after a period called the repair cycle time (RCT). If the failure is classified as NRTS, it is shipped to the depot for repair and the base has what is termed a part "on order." The depot, once a part is requisitioned, will ship a replacement part even before any failed part arrives for repair, providing the depot has a serviceable item in stock. Upon arrival of the failed part, the depot must make a determination as to the reparability of the item. If the item is considered beyond repair, it is condemned and a demand is placed on procurement for a replacement. If the part is, however, repairable, the depot, which usually has abundant facilities, will repair the item or if necessary, send the item to a contractor for repair. Once the item is either repaired or procured, it is placed in the

depot inventory. Obviously, if there were no stock available when the demand was made, a newly repaired or procured item would have to satisfy the current depot demand and immediately be sent to the base with the longest outstanding requisition. Consequently, all inventory items are in base repair, base stock, depot repair, depot stock, transportation, or in the procurement cycle due to condemnation. The system for consumables is similar with the exception that there are no repair activities and the economic order quantity principles of inventory apply.

Another activity, though not a formalized portion of the supply system, is cannibalization. When failures occur and no items are available from base inventory or base maintenance, aircraft grounded due to failure of other items may be used as an additional means of supply. This procedure prevents another grounding with no immediate harm to the donor aircraft which will receive the resupplied items when they become available.

It should be noted that the system is not as closed as it would appear. There are a few aircraft systems which are common to more than one service. Consequently, in order to avoid duplication among the services, some common parts may be received from another service activity such as the Navy for the A-7 and the Army for the Huey helicopter. Also, lateral support between bases cannot be overlooked. For instance, if a base has a demand which cannot be filled from base or depot stock, another base which

has the same or similar aircraft may be able to satisfy the demand. Refer to Figure 1 for a pictorial depiction of the supply process.

#### Aircraft Status

In order to discuss and understand the BLSS computations, it is necessary to be familiar with the ways of classifying aircraft with respect to their operational capability.

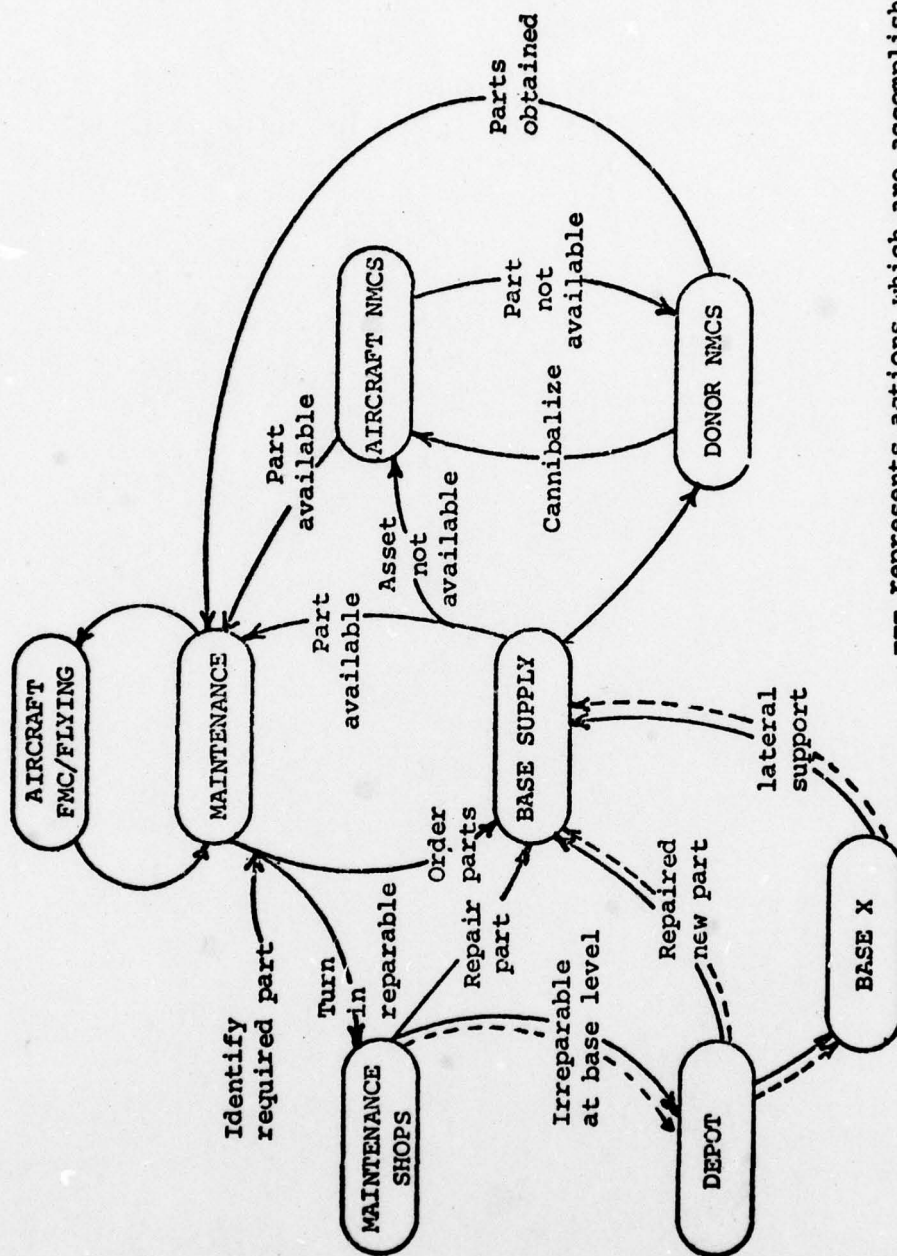
FMC - Full Mission Capable. The aerospace vehicle must be able to fly all peacetime and wartime missions to be in this class.

PMC - Partial Mission Capable. The aerospace vehicle must be able to fly at least one of its wartime missions to be in this class.

NMC - Not Mission Capable. The aerospace vehicle must be unable to perform any wartime missions for this class.

In order to be more explicit, the codes PMC and NMC will have a suffix which will describe the reason why they are classified the way they are. For example, the letter "M" will be used for maintenance, "S" for supply, or "B" for both maintenance and supply. In addition, NMCM and NMCS will reflect whether the needed maintenance is scheduled or unscheduled. Since this study concerns the area of supply, it is important that the definition for NMCS be noted. NMCS is assigned when:

The aerospace vehicle cannot fly any of its wartime missions due to lack of parts for subsystems on the MAJCOM basic systems lists. This status condition will also be reported for aircraft without a wartime mission when unable to fly any of its assigned missions (Ref 5:2-12).



--- represents actions which are accomplished in peacetime but which may be curtailed in wartime.

**Fig. 1. Model of Supply Process**

Thus, in order to declare an aircraft NMCS, all local means of accounting for a part must be exhausted including parts in base repair, since it is possible to have a downed aircraft whose failed part is in local repair and not assign the aircraft NMCS. This condition may also exist when the failed item is required for the mission and it cannot be readily reparable at the base. This condition is known as Awaiting Parts.

It is very important that the distinction be made between the two uses of NMCS. The term is used when referring to aircraft and parts, but not in the same way. When it is used in connection with aircraft, the term implies a certain degree of degradation in the supply system. When used with parts, it would appear to be only a supply system performance measure. However, the correspondence between NMCS for aircraft and parts may not be one for one. That is, an NMCS part does not necessarily produce an NMCS aircraft. For example, one aircraft could be NMCS and have multiple failed items which are all considered NMCS parts. This paper will refer to NMCS aircraft only.

#### Base Stock Levels

This section will describe the method of determining authorized base reparable stock. This quantity is known as the requisitioning objective and is composed of the demand level and the War Reserve Material.

The quantity of WRM for a particular part is determined by the using command based on war planning/programming and

separate guidance. The System Manager also has an input in the process, however, and he has the final approval or disapproval of kit contents.

All BLSS WRM can be co-mingled with peacetime stock (Ref 6:1, 11, 4). The purpose of the stock is not, however, to fill daily needs. In order to maintain serviceability, the stock is subject to all shelf life criteria and required maintenance in the same manner as peacetime levels.

Accounting visibility for BLSS stock must be maintained. The only uses for which the WRM may be authorized in peacetime are: to aid in relief during a disaster; to support contingency operations; to relieve an NMCS condition; to conduct operational readiness tests; or to support other vital emergency operations not anticipated or specified (Ref 5:2-14). The use of BLSS spares for any of the reasons just mentioned must be authorized by the using command and in accordance with Air Force Regulation 400-24.

The remainder of the authorized stock is comprised of three parts: the Repair Cycle Time Quantity, the Order and Ship Time Quantity, and the Safety Level Quantity. The Repair Cycle Time Quantity is that quantity of stock necessary to meet the demands while parts are in base level in-process inventory. The Order & Ship Time (O&ST) Quantity is the stock which is necessary to maintain operations for the average time required to obtain replacements from the depot for NRTS reparable and condemned items. The Safety Level Quantity is that stock authorized to reduce

the effects of any random fluctuations in O&ST, Repair Cycle Time, or demand.

The stock level authorization is based on the daily Demand Rate (DR). DR is calculated as follows:

$$DR = \frac{\text{Total Demands}}{\# \text{ days over which demands occurred}} \quad (1)$$

The demand rate is based on a minimum of 180 days experience. If demand history is not available for a full 180 days, 180 will be used in Eq (1) in order "to minimize the inflationary effect" (Ref 6:1, 11, f, 9). This should prevent stockage based on random fluctuations in demand over short periods of time. In any case, when using actual data, no more than 365 days may be used and they should be the most recent. Total Demands in the daily DR equation do not include demands classified as non-recurring or demands for initial stockage such as the demand required to attain a new level. Thus, the authorized stock level is the sum of the Repair Cycle Quantity, the O&ST Quantity, and the Safety Level Quantity (Ref 6:1, 11, 6). In mathematical notation:

$$\text{Auth. Level} = \text{RCQ} + \text{O\&STQ} + \text{SLQ} \quad (2)$$

where RCQ (Repair Cycle Quantity) = DR x BRR x BRCT

BRR (Base Repair Rate) = RTS/Total Demands

BRCT = Base Repair Cycle Time

O&STQ = Order and Ship Time Quantity  
= DR x (1 - RTS) x O&ST

RTS = Reparable This Station

$$\begin{aligned} \text{SLQ} &= \text{Safety Level Quantity} \\ &= K \sqrt{3(\text{RCQ} + \text{O\&STQ})} \end{aligned}$$

K = Constant = 1

In order to calculate the levels, it is necessary to calculate or obtain information on base repair times, base repair rates, and O&ST. Base repair cycle time is computed as the average time required to repair an item or the specified maximum (either six or nine days). The order and ship time used should be actual historical data, if possible, plus two days which represent an average of base processing time.

If it is desired to reduce an authorized level to zero, there must not have been any demands in the past 180 days and the DR must be below .0054 (Ref 6:1, 11, 3f). In other words, there must have been fewer than two demands in the past year. If no level has been previously authorized and the need arises, a new level may be established if there were two recurring demands within the last 365 days (Ref 6:1, 11, 3f). Levels may not, however, be changed at will.

Changes to demand levels will not be made more frequently than once each 90 days with the following exceptions: (1) Approval of the major command, (2) The date of the last demand exceeds 365 days for reducing a level to zero, (3) When the second demand occurs (Ref 6:1, 11, 2).

Sometimes the previously explained procedure is not adequate for predicting an authorized level. In this case, special levels may be authorized in lieu of that calculated. This may occur in situations where the future activity of

a unit may be substantially different than past activity such as may be the case just before a long exercise or deployment. The use of special levels is discouraged, however, because they "may result in the degradation of support to other bases whose levels are based on demand experience" (Ref 6:1, 11, 8g). Special levels are not meant to be stock over and above the authorized level; but a way to obtain a more adequate authorized stock level for future activity.

#### BLSS Requirement Generation

Each year, Hq. USAF LGX announces and circulates an annual WRSK/BLSS authorization letter which requires a full review of all WRSK and BLSS kits by the System Manager (SM), Item Manager (IM), and the using command. The review is conducted in the same manner as an initial kit establishment meeting which is normally initiated by the SM. The process begins with the SM presenting a list of candidates or the existing list with any additions or deletions. The list contains both reparable and economic order quantity (EOQ) items. Normally, most EOQ items are considered a part of "bench stock" and as such, are handled through another type of funding. However, there are two instances in which EOQ items are considered part of the BLSS. First, whenever an EOQ item must be removed and replaced (destroyed) in order to get to a reparable item and second, to repair reparable items. The practice of excluding most EOQ items

from WRM kit construction is by policy and if desired, there is nothing to preclude the inclusion of any WRM stock in the methods (to be developed later) for consideration as entries into the BLSS kit.

Each item on the candidate list is screened using the following considerations: probability of demand, mission essentiality, and maintenance capability. As items are eliminated, they are placed on another list which is screened for safety of flight and/or time change items. If any of these items were eliminated, they are placed on separate lists.

There are now four lists: the BLSS primary candidates list, the eliminated time change items list, the eliminated safety of flight items list, and other eliminated items. The primary candidates list is then used by AFLC to compute the quantity requirements of those items listed. All items are treated as though they follow a remove, repair, and replace maintenance concept. The actual computational process will be addressed later.

Following quantity development, the list is reviewed by applicable IMs and the using command who can then make inputs to the list. The SM will subsequently review any recommendations and begin negotiating any recommendations with which he does not concur. The SM uses the safety of flight item list and the time change item list to aid in his negotiations. The SM, although he allows and participates in negotiations, maintains final approval authority

for the BLSS (Ref 1:14-30).

#### AFLC Computation Description

Presently, AFLC is using a steady state concept to compute the BLSS. Since the BLSS assets are merely the difference between assets required to fill peacetime pipelines and wartime pipelines (specifically the base repair pipeline and the order and ship time pipeline), the BLSS is computed using the following formulas:

Peacetime requirement =

$$(BRR \times BRC \times ODPP \times QPA) + (DDR \times O\&ST \times ODPP \times QPA)$$

and Wartime requirement =

$$(BRR \times BRC \times ODPW \times QPA) + (DDR \times O\&ST \times ODPW \times QPA)$$

where

BRR = base repair rate expressed in demands per 100 flying hours.

BRC = base repair cycle expressed in days.

ODP = one day flying hour program expressed in hundreds of hours. (ODPP - during peacetime) (ODPW - during wartime).

QPA = quantity per application.

DDR = depot demand rate expressed in demands per 100 flying hours.

O&ST = base order and ship time expressed in days.

The peacetime and wartime requirements each have safety levels attached to the above computations which are:

$$\text{Peacetime Safety Level} = \sqrt{3(\text{Peacetime Requirement})}$$

and

$$\text{Wartime Safety Level} = \sqrt{3(\text{Wartime Requirement})}$$

Thus, the present BLSS Requirement is equal to:

(Wartime Requirement + Wartime Safety Level) -

(Peacetime Requirement + Peacetime Safety Level)

(Ref 7:9, 10).

In a wartime situation, demands will increase, but restocking will not increase as rapidly. The number of inbound units from base repair will depend on the number of failures which occurred the base repair cycle ago or the production rate, whichever is smaller. As an example, note the change from 4 to 8 on day 5 in Table I. Likewise, the number of units inbound from the depot will depend on the number of failures the order and ship time plus some depot delay time ago or the production rate, whichever is smaller. This can be seen in the change from 1 to 2 after 10 days of increased failures in Table I. Consequently, inbound items will only account for the equivalent to peacetime failures, with the BLSS accounting for the remaining wartime demands. Thus, the BLSS is only to cover that time interval from D day until both the base and depot pipelines could adjust and cover all demands with inbound units. This steady state environment in both peace and war makes the computation simple; however, the actual war scenarios are not steady state. Thus, a new computational method has been proposed which incorporates surge activity and shows quite different results as shown by Tables I and II. It can be seen that without surging, a 26 item BLSS would be sufficient; whereas with surging, a 48 item BLSS would be

Table I  
Wartime without Surge\*

	1	2	3	4	5	6	7	8	9	Days 10	11	12	13	14	15
Demand	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Out of Base Repair	4	4	4	4	8	8	8	8	8	8	8	8	8	8	8
Out of O&ST	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2
Deficit	-5	-5	-5	-5	-1	-1	-1	-1	-1	-1	0	0	0	0	0

\*BRC = 4 days  
O&ST = 10 days

Table II  
Wartime with Surge\*

	1	2	3	4	5	6	7	8	Days 9	10	11	12	13	14	15
Demand	15	15	15	15	15	15	15	15	10	10	10	10	10	10	10
Out of Base Repair	4	4	4	4	12	12	12	12	12	12	12	12	8	8	8
Out of O&ST	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3
Deficit	-10	-10	-10	-10	-2	-2	-2	-2	+3	+3	+5	+5	+1	+1	+1

\*Surge = 8 days  
BRC = 4 days  
O&ST = 10 days

required to meet all demands. It is important to note that any reduction from 48 items would result in demands not met, even with the overages from day nine forward.

The proposed method of BLSS computation uses the logic of Table II with the addition of a safety level.

The following formulas apply to the proposed BLSS:

a. Demands:

- (1)  $TDR \times ODP \text{ surge} \times QPA$  (day 1 through surge period)
- (2)  $TDR \times ODP \text{ sustained} \times QPA$  (surge days +1 day through 30 day period)

b. Out of Base Repair

- (1)  $BRR \times ODP \text{ peace} \times QPA$  (day 1 through BRC)
- (2)  $BRR \times ODP \text{ surge} \times QPA$  (BRC +1 day through BRC plus surge days)
- (3)  $BRR \times ODP \text{ sustained} \times QPA$  (BRC plus surge days plus one through 30 days)

c. Out of O&ST

- (1)  $DDR \times ODP \text{ peace} \times QPA$  (day 1 through O&ST)
- (2)  $DDR \times ODP \text{ surge} \times QPA$  (O&ST plus one day through O&ST plus surge days)
- (3)  $DDR \times ODP \text{ sustained} \times QPA$  (O&ST plus surge days plus one through 30 days)

The deficit row in Table II is computed by summing the out of base repair and out of O&ST and then subtracting the number of demands. The deficits can then be added and called 'A' which represents the difference between the required wartime and peacetime assets.

Peacetime Requirement =

$$Y = (BRR \times BRC \times ODP \text{ peace} \times QPA) + (DDR \times O\&ST \times ODP \text{ peace} \times QPA)$$

Total Wartime Requirement =  $Y + A$

Safety Level for Total Wartime Requirement =

$$\sqrt{3(Y + A)}$$

Peacetime Safety Level =  $\sqrt{3Y}$

Thus,

$$BLSS = A + \sqrt{3(Y + A)} - \sqrt{3(Y)} \quad (3)$$

Any fractions of units are rounded according to standard mathematical convention (Ref 8:1, 9).

Thus, the proposed BLSS computational technique accounts for surge activity and is completely deterministic in nature. It does not account for any other variable such as cost. A method will now be examined which can provide a maximum amount of support of one measure for a specified cost.

#### METRIC

The Multi-Echelon Technique for Recoverable Item Control (METRIC) is a mathematical model capable of determining base and depot stock levels for a group of recoverable items. Its primary purpose is to optimize base and depot stock levels for each item, subject to a constraint on system investment. This technique has been applied to many other systems including a derivative of METRIC known as D028 which is used to establish stock levels at Air Force bases (Ref 9). Since METRIC is so widely known and a derivative of it will be utilized later, a review of the technique will be presented.

The objective of METRIC is to minimize the sum of expected backorders on all recoverable items at all pertinent bases. The constraint on this objective function will be the budget. It should be pointed out that the Rand Corp., designer of METRIC, utilizes a different definition of backorders than that used by the Air Force. Rand interprets a demand as a backorder any time there is an unsatisfied demand at base level. Even if a unit is in base repair, Rand still classifies the demand as a backorder (Ref 4:6). The Air Force definition is the same except that if a unit is in local base repair, the demand may not constitute a backorder. In other words, a part cannot be at or reparable at the base in order to be classified a backorder.

In the case where excess demand is backlogged, the expected number of backorders at a random point in time is expressed as:

$$B(S) = \sum_{X=S+1}^{\infty} (X - S)p(X|\lambda T)$$

where  $p(X|\lambda T)$  is a compound Poisson probability density function for a mean customer rate  $\lambda T$  and  $S$  is the authorized stock level (Ref 4:14).

Thus, METRIC optimizes the following:

Minimize  $\sum_i \sum_j B(S_{ij})$   
 subject to:

$$C_i S_{ij} \leq K$$

where  $S_{ij}$  = stock of item  $i$  at base  $j$

$C_i$  = unit cost of  $i$ th item

$B(S_{ij})$  = expected backorders for part  $i$  at base  $j$

$K$  = budget restriction

It is noted that the expected number of backorders is a convex function since

$$B(S+1) - B(S) = -\sum_{X=S+1}^{\infty} p(X|\lambda T)$$

METRIC then determines the optimal allocation of the parts among the bases so as to minimize the sum of expected backorders at all bases. This is accomplished by a simple marginal allocation which produces the largest decrease in expected backorders per dollar invested (Ref 4:16). It remains to be determined as to what the relationship is between the number of downed aircraft and the number of expected backorders in supply.

#### Aircraft Status and Backorders

The relationship between the two variables mentioned above is not completely known. If all items were essential and would result in NMCS, then there would be a 1:1 correspondence, with the exception of more than one backorder per aircraft. However, many parts are neither essential nor grounding, such as in redundant systems where a backorder may not reflect an actual grounding but only a partial loss in mission capability. Another instance where a backorder may occur and not a grounding or at least a reported

grounding is when a failure occurs, a replacement is not in stock, and the part is reparable at the base. As discussed earlier, if a replacement for a failed part may be located in base supply or base maintenance, the aircraft may not be grounded for supply. Thus, the actual relationship between backorders and grounded aircraft cannot be stated for all parts since some parts cause grounding under individual circumstances and other parts only result in mission degradation.

#### Previous Related Research

In recent years there has been a great deal of research in the area of WRSK calculations which are not drastically different than what could be applied to a BLSS kit. For many years, AFLC computed their WRSK requirements using conventional means very similar to the conventional methodology for the BLSS which was discussed earlier. No consideration was made for optimizing a kit design for a given investment.

During the late sixties and early seventies, the Rand Corporation performed many studies of Air Force inventory policies and WRSK calculations. One of special interest compared the design of alternative measures of supply performance: namely fill rate, backorders, operational rate and NORS. The term NORS is synonymous with NMCS. Operational rate is defined as the probability of no NMCS: that is, there will be no backorders in base supply. The Rand

report concluded that with respect to the expected NORS criterion, the techniques were ranked as follows: (1) Operational rate; (2) Expected backorders; (3) and Fill rate. Also, the report showed that all four performance measures provided approximately the same inventory levels as inventory investment increased (Ref 10:10, 11).

A second study formulated a mathematical model which maximized the modified operational rate (MOR). MOR is defined as the probability of meeting all demands for spares given  $k$  aircraft are available for cannibalization. A repair capability was assumed possible with the study showing a technique for employing marginal analysis to perform optimization. The primary result of this study was that explicit consideration of available peacetime assets in the WRM calculations would substantially reduce costs or increase supply performance (Ref 11:4-17).

Another interesting study which was performed by the Logistics Management Institute (LMI) in 1972 attempted to minimize expected NMCS subject to an investment constraint. The model assumed no cannibalization and allowed for two or more simultaneous failures on an aircraft by allocating the expected number of backorders equally over all aircraft in the unit. The intent of the LMI study was to compare NMCS and backorders minimization with hypothetical data. The results showed that the backorders model gave too much preference to low cost items which produced a slightly

higher expected NMCS. (Ref 12:54-65).

Another study, entitled Saber Readiness - Delta by Air Force Studies and Analysis (AF/SA), was directed toward the identification of ways of lowering investment costs of WRM without reducing the effectiveness of WRSKs. The study used simulations to analyze the effects of maintenance and resupply policies and showed that any pooling of WRSKs was beneficial. In addition, the simulation model was capable of designing an optimum WRSK by estimating the marginal number of sorties per dollar investment for each item, with the item having the largest marginal value the next added to the kit. The study concluded that optimization techniques were better than conventional methods in designing WRSKs (Ref 10:13).

A recent AFIT thesis by Glazener and Tinder, in response to Saber Readiness - Delta criticism, designed an optimal kit based on the fill rate criterion (Ref 13:22). The authors felt that fill rate reflected the ability of a WRSK to meet immediate demands which was of primary importance to them. Unfortunately, they did not relate fill rate to operational effectiveness. When Eberling compared a conventional kit with the Glazener and Tinder kit, only a marginal improvement in expected NORS resulted from the use of the fill rate criterion.

In 1977, the Pacific Air Forces (PACAF) became concerned about WRSK capability in supporting sortie surges. This concern resulted in a model which uses a non-stationary

Poisson probability distribution to estimate daily requirements for each item. Any backorders by day are then recorded with the highest daily backorder of each item becoming the required level in the WRSK. A backorder criterion is used to determine peacetime levels. PACAF has also developed a WRSK evaluation model which calculates expected NMCS and accounts for sortie surges (Ref 14: 5-10).

The current system used by AFLC for computing WRSK levels is known as the D029 system. D029 calculates the total cost of a conventional WRSK along with its performance as measured by expected NMCS and expected backorders. Marginal analysis is then used to compute a kit with the same or fewer expected NMCS and expected backorders. An optimum cannot be determined in all cases because the NMCS expression is the sum of products. This system has been incorporated into many existing weapon systems and has resulted in substantial savings.

### Conclusions

Over the last few years, considerable research has been conducted in optimizing the design of WRSK kits, however, it has only been recently that interest has been shown in optimizing BLSS construction. Thus, the next chapter will be directed toward the development of a criterion directly relatable to unavailable aircraft.

### III. Cumulative Density Function for Downed Aircraft

#### Introduction

Past research has been predominately in areas such as expected backorders, fill rate, operation rate, and expected MNCS. Unfortunately, few of these measures seem to actually measure the real point of interest to the operational commander, which is, how many aircraft are available to perform the mission. All of the previously mentioned measures are predominately supply measures. Thus, a measure which can be used by the supply system as well as having meaning to the operational commander is needed.

A Rand report addressed this issue in 1969 and developed a measure of downed aircraft which they called expected NORS (Ref 15). This measure will be referred to as expected downed aircraft in order to avoid confusion with traditional NORS. This study attempts to go one step further than Rand in the supply system breakdown by considering redundant parts.

#### Assumptions

As in all studies of a real world situation, some assumptions must be made in order to begin. It is assumed in this study that:

1. There is perfect cannibalization. This implies that all parts can be removed safely without damage and be

available for immediate use elsewhere.

2. There is instantaneous remove and replace capability of failures. This also includes cannibalizations which involve another removal activity each time there is a failure when no stock is on hand.

3. There is adequate manpower available for any necessary cannibalizations.

4. Any aircraft to be cannibalized is always available for such activity. This implies that an aircraft with a good part may not be flying a mission when the part is needed. This is not thought to be as bad as it may seem since most combat missions, especially by fighters, do not last for long periods of time.

5. All supply and maintenance activities are of the modular type. In other words, there is no breakout to distinguish between Line Replaceable Units (LRUs) and Shop Replaceable Units (SRUs).

6. All failures are distributed according to the exponential probability density function.

7. All failures are independent of one another.

8. Battle damage and battle attrition are not considered due to the non-availability of a universally accepted way of predicting the extent of either factor.

9. All failures are random and the number of failures within any time period is distributed according to the Poisson probability density function.

### Derivation of the Cumulative Density Function

The cumulative density function of interest should reflect the distribution of downed (unavailable) aircraft which cannot contribute to the mission of the assigned unit. To develop this cdf, it is first necessary to define and account for all parts which could cause either directly or indirectly the grounding of an aircraft. Further, it is necessary to assume that any of the defined parts which are redundant (not absolutely necessary for flight) can be cannibalized from any aircraft within the fleet. Thus, stock associated with each part consists of:

$$S_i = L_i + R_i \times AC$$

where

$S_i$  = stock of part  $i$

$L_i$  = on hand + on order + in maintenance - backorders for parts of type  $i$

$R_i$  = number of redundant parts  $i$  per aircraft

and  $AC$  = number of aircraft in the local fleet.

When thinking of redundant parts, all parts which belong to a redundant system and those parts which may be part of a designed safety level should be considered as part of the available stock during wartime situations. When considering the stock level in this way, it is important to recognize its dynamic nature. Stock level now becomes a random variable subject to the number of downed aircraft.

Obviously, an aircraft is grounded whenever  $S_i$ , which includes any good spares made available by other grounded aircraft, is depleted and one more failure occurs. Thus, groundings do not occur on a one-to-one basis with failures because after  $S_i$  is depleted, there will not be another grounding until the necessary spares of another donor aircraft are also depleted. Given this approach, it is necessary to consider in the same manner all of the parts on the aircraft which cause grounding. Consequently, the probability of a downed aircraft depends on the product of the individual part probabilities of failure. Since and exponential failure density is assumed, the number of failures (demands) would be distributed as a Poisson over the interval of interest with a mean equal to the reciprocal of the exponential parameter. As a result, the probability of a grounded aircraft due to a single type of part is a summation of the probabilities over the available pool of parts. The pool is defined as  $S_i$  plus the number of downed aircraft times the essential number of parts of type  $i$ . The mathematical notation for the probability of having  $y$  or fewer unavailable aircraft could be expressed as the product of summations of Poisson probabilities over  $Z_i/N_i$ . In mathematical symbology:

$$P(y \leq Y) = P(Z_i/N_i \leq Y, i=1, \dots, n)$$

where  $Z_i = X_i - S_i$

$X_i$  = number of failures or demands for part  $i$

$N_i$  = number of essential parts of type  $i$  on each aircraft

$n$  = number of parts which could cause aircraft grounding

and  $Z_i/N_i$  should always be rounded up to the next integer value.

Expanding:

$$\begin{aligned}
 P(Y \leq Y) &= \prod_{i=1}^n \sum_{Z_i/N_i=0}^Y p(Z_i/n_i = Z_i/N_i) \\
 &= \prod_{i=1}^n \left[ \sum_{X_i=0}^{S_i+Y \cdot N_i} \frac{(G\lambda_i)^{X_i} e^{-G\lambda_i}}{X_i!} \right] \quad (4)
 \end{aligned}$$

where  $G$  = time interval of interest

$\lambda_i$  = demands per unit of time

This discussion can be extended to the probability of exactly  $Y$  grounded aircraft which is equal to the difference between the cumulative probabilities for the last possible part failure producing the  $Y$ th grounded aircraft and the last possible failure producing the  $Y-1$  grounded aircraft. That is,

$$P(Y=Y) = P(Y \leq Y) - P(Y \leq Y-1)$$

#### Time Interval of Interest

The times which affect the parts in a resupply and maintenance system are Repair Cycle Time ( $a$ ) and Order and Ship Time ( $\theta$ ) along with the Not Repairable This Station (NRTS) rate. There is another interval of time which is discussed by Muckstadt and must be considered if the depot

pipeline is included (Ref 16:476). This time interval is known as "depot delay" and represents that period of time when the depot has no "on hand" stock and must wait for a unit which is in "in-process" inventory. The depot delay, as Muckstadt refers to it, is computed by calculating expected backorders and dividing by the expected daily demand to receive the dimension of delay days per demand. Thus, depot delay is:

$$DD = \text{Expect Backorders/Expected Daily Depot Demand}$$

$$= \sum_{X > S_0} (X - S_0) p(X | \lambda_i T) / \lambda_i$$

where  $S_0$  = depot stock level

$$\lambda_i = \text{expected daily depot demand rate}$$

and  $T$  = depot repair cycle time in days

The density function for  $X$  is Poisson. Base delay will not be considered because this study will remain on the LRU, not SRU level.

In order to present this discussion more clearly consider the following:

$$P_{t+1} = P_t + N_{t-a} + M_{t-\psi} - X_t$$

where  $P_t$  = number of parts of type  $i$  in the available pool at time  $t$

$$\begin{aligned} X_t &= \text{number of failures of type } i \text{ in time } t \\ &= N_t + M_t \end{aligned}$$

$N_{t-a}$  = RTS failures of part  $i$  in time  $t-a$  units ago. This results in the number of parts  $i$  which will return to available stock at time  $t$ .

$M_{t-\psi}$  = NRTS failures  $\psi$  time units ago

and  $\psi$  = Order and Ship Time plus Depot Delay.

It is assumed that:

$$N_t \approx P(R\lambda_i) \quad \text{Poisson Distributed}$$

$$M_t \sim P((1-R)\lambda_i)$$

where  $\lambda_i$  = daily demand for part  $i$

and  $R$  = base repairable rate

$$0 \leq R \leq 1$$

Utilizing an inductive approach:  $a < \psi$ ,  $K = \min(a, \psi)$

$$P_1 = P_0 - N_1 - M_1$$

$$P_2 = P_1 - N_2 - M_2$$

$$P_a = P_{a-1} - N_a - M_a$$

$$P_{a+1} = P_a + N_1 - N_{a+1} - M_{a+1}$$

$$= P_0 + N_1 - (N_1 + \dots + N_{a+1}) - (M_1 + \dots + M_{a+1})$$

$$= P_0 - (N_2 + \dots + N_{a+1}) - (M_1 + \dots + M_{a+1})$$

$$P_\psi = P_{\psi-1} + N_{\psi-a} - N_\psi - M_\psi$$

Thus,

$$P_K \sim P_0 - P(\lambda_i K) \quad \text{for } 1 \leq K \leq a$$

$$P_K \sim P_0 - P((Ra + (1-R)K)\lambda_i) \quad a \leq K \leq \psi$$

$$P_K \sim P_0 - P((Ra + (1-R)\psi)\lambda_i) \quad \psi < K$$

$R$  = Repairable This Station Rate

and the time interval of interest is:

$$G = \psi(1-R) + Ra$$

This result appears reasonable since the sum of Poisson distributions is also a Poisson with mean equal to the sum of the means of the individual Poissons.

G will be used to represent the interval of interest because it is desired to observe the described system in steady state when parts will be returning from both the depot and the base maintenance facility. Since the BLSS kit does not move, all of the supply and maintenance activities that support the base during peace should continue during the early phases of war. It is assumed that all applicable delays at the depot and base have been accounted for in the determination of the means for  $\psi$  and  $\underline{a}$ . Further, it is assumed that the determination as to the necessity of a part can be made such that parts may be classified as redundant or not. All parts considered redundant should be considered part of stock with further stock available as aircraft become grounded.

#### Summary

Thus, a cumulative density function which provides the probability of a certain number or less of downed aircraft has been devised. The cdf assumes 100% cannibalization and the number of failures is distributed Poisson. This cdf now provides a means of looking at the primary operational issue of "the number of available aircraft." The next chapter will exhibit a means of using the cdf in constructing BLSS kits.

#### IV. Methodology to Optimize BLSS Performance

##### Introduction

Having a cumulative density function for the probability of Y or fewer downed aircraft does not immediately point to the objective function one should use in employing the cdf. Fortunately, the only restriction on the BLSS kit should be the budget since, unlike the WRSK kit, the BLSS kit is virtually, within reason, without physical limitations. Several objective functions were considered such as:

1. Maximize the expected utility of available aircraft.
2. Minimize the expected number of downed aircraft.
3. Maximize the probability of a certain number of available aircraft.
4. Maximize the probability of a certain number or fewer of aircraft NMCS.

Of those listed, maximizing the probability of a certain number or fewer of aircraft NMCS seemed the most appropriate because it is a variable of interest and it is less complex than the other functions.

##### Developing the Selection Criteria

It is desired to choose an  $S_i$  in order to maximize the  $P(y \leq Y)$  subject to a budget constraint. This may be stated as an integer, non-linear programming problem as follows:

$$\text{Maximize } P(y \leq Y) = \prod_{i=1}^n \left[ \sum_{X_i=0}^{S_i + SL_i + n_i Y} p_i(X_i) \right]$$

subject to:

$$\left\{ \sum_{i=1}^n C_i S_i \leq B, s \in U \right\}$$

where U is the set of n-tuples of non-negative integers

$$(S_1, \dots, S_n),$$

$$B, C_i > 0, i=1, \dots, n$$

$S_i$  = additional WRM stock level of part i

$SL_i$  = authorized peacetime stock level of part i

B = WRM budget

$C_i$  = unit cost for part i

$p_i(X_i)$  = Poisson density function

$n_i$  = quantity per application

A more convenient means of expressing the objective function may be with the introduction of logarithms. When this is done, the objective function becomes:

$$\text{Maximize } \ln P(y \leq Y) = \sum_{i=1}^n \left\{ \ln \left[ \sum_{X_i=0}^{S_i + SL_i + n_i Y} p_i(X_i) \right] \right\}$$

This is permissible since only a monotonic transformation has been made which has the property that if one is maximized, the other is also.

The LaGrangian may then be formed:

$$L = \sum_{i=1}^n \left\{ \ln \left[ \sum_{X_i=0}^{S_i + SL_i + n_i Y} p_i(X_i) \right] \right\} - \lambda \left( \sum_{i=1}^n C_i S_i - B \right)$$

According to Fox (Ref 16:211-212), since  $\lambda \geq 0$  and  $S_i^*$  (its optimum value) is realizable, then  $S_i^*$  maximizes  $\ln P(y \leq Y)$  and in turn,  $P(y \leq Y)$ . Consequently, the problem reduces

to one of marginal analysis which is solved by an iterative technique. To perform the iterations, begin by setting  $S_i=0$  for each item  $i$ . Then find the item  $i$  for which the expression:

$$\ln \left[ \sum_{X_i=0}^{S_i+SL_i+n_iY+1} p(X_i) \right] - \ln \left[ \sum_{X_i=0}^{S_i+SL_i+n_iY} p_i(X_i) \right] - \lambda C_i = 0$$

is a maximum.

This expression can be simplified by solving for  $\lambda$  to receive the following:

$$\lambda = \ln \left( 1 + \frac{p(X=F_i+1)}{P(X \leq F_i)} \right) / C_i$$

where  $F_i = S_i + SL_i + n_iY$  (Ref 17:210).

Once a selection has been made, increment  $S_i$  by one and repeat the procedure until the constraint has been satisfied with no more possible purchases. In the Lagrangian,  $\lambda$  represents the marginal aid provided per dollar invested. In other words,  $\lambda$  is the benefit provided by purchasing one more item of type  $i$ .

Note that the normal techniques of differentiation cannot be used because  $P(X \leq F_i)$  is restricted to integer values since the failures are assumed to be Poisson distributed. This problem can also be solved by using the well known method of finite differences where the differential equation is replaced by a difference equation since the continuous region where the solution is desired has been replaced by discrete points. Consequently, the

finite differences method requires a comparison of all possible combinations of  $P(X \leq F_i)$  in order to determine the optimal combinations (Ref 18:15). A much more appealing solution is the heuristic process based on marginal analysis. Marginal analysis is taken from economic production theory and merely states that "an efficient mix of productive inputs is that mix for which the ratio of marginal product to marginal cost is the same for each input" (Ref 19:1). Also, it might be useful to think of the dual problem, remembering that  $\lambda$  should provide an indication as to the increase in benefits for each additional investment.

The problem as formulated is one of a type of integer programming problem which requires the use of some type of bounding technique in order to determine an optimum. Unfortunately, these techniques utilize enumeration procedures for finding an optimal solution which may involve, and usually do, a very large number of iterations. For example, as few as 10 variables with each having 10 feasible values can produce as many as  $10^{10}$  feasible solutions. Even with today's computers performing one million arithmetic operations per second, the number of enumerations could be too time consuming for this size of problem. (Ref 20:699). The number of necessary enumerations can be reduced by applying a Branch and Bound technique; however, the number of iterations is still very large and somewhat prohibitive. This procedure will,

however, produce an exact answer and not an approximation as do the techniques previously discussed.

### Methodology

Due to the disadvantages of using an exact procedure, it was decided not to pursue the integer programming solution. Instead, efforts were concentrated on a viable approximation technique, namely marginal analysis.

Recall that the model as originally constructed considered all parts not absolutely necessary for flight as a part of base stock for that particular item. This requires that a definite distinction be made between the safety of flight items, those items part of redundant systems, and those parts absolutely necessary for mission accomplishment. Unfortunately, this information is not available at this time. As a result, a position was utilized for which data exists and allows a solution. From this point on, parts will not be categorized further than quantity per application.

The methodology chosen to pursue utilized Equation 5 which is a maximization of the probability of Y or fewer grounded aircraft expressed as the function of a LaGrangian. This equation was used to construct a matrix of values representing its right hand side. The top row, which will contain the largest  $\lambda$  in the matrix, was then searched for the particular value of  $\lambda$  associated with that iteration. That  $\lambda$  referenced a part which,

when found, was purchased provided that the additional cost of this item did not cause budget overshoot. If overshoot occurred, the item was not purchased and the algorithm went back to the original matrix and made another choice. If no other choices were available because the difference between the sum of the present purchases and the budget was smaller than the lowest dollar valued item considered, the procedure terminated and the kit was made.

There have been other approaches taken to solve this same problem which are interesting in their own right. For instance, Rand chose to formulate the problem as follows:

Minimize  $\sum_j b_j K_j$   
 subject to:

$$\prod_j g_j(K_j + Ca_j) \geq S$$

where  $S$  = a prespecified operational rate

$K_j$  = the quantity of item  $j$  in the kit

$b_j$  = unit cost of item  $j$

$C$  = aircraft available for cannibalization

and  $a_j$  = quantity per application

Marginal analysis was then applied to receive the relationship:

$$\frac{\log g_j(K_j + Ca_{j+1}) - \log g_j(K_j + Ca_j)}{b_j} = \lambda \quad (6)$$

Their technique seems very simple and very close to that

explained above. They began by choosing an "S" and then allowed the algorithm to begin its search and choose from the top row of the previously shown matrix the highest value. They do not use budget as a hard constraint, only the chosen "S". This method is followed until the constraint is satisfied.

Rand also used the method of setting  $K_j$  equal to a value and then searching for the item whose ratio is the largest. The chosen stock level is then increased by one. The procedure continues until the budget constraint is exceeded.

Another method was used by Rand which was actually a minimization of expected NMCS aircraft. To solve this, they set:

$$d_c = \prod_{j=1}^n F_j(K_j + a_j c) \quad c=0,1,\dots,C.$$

and then they optimized

$$\sum_{c=0}^C d_c \sum_{j=1}^n \log F_j(K_j + a_j c) - \lambda \sum_{j=1}^n b_j K_j$$

The optimization was performed for various values of  $\lambda$ , until a prespecified cost was met. Then the values for  $d_0, \dots, d_C$  were reset and the process repeated. These steps were followed until the values for  $d_0, \dots, d_C$  stabilized (Ref 15:25-26).

Using a fill rate criterion, Glazener and Tinder used another approach. They developed a cost-effectiveness

curve by (Ref 13:26):

1. Setting  $\theta$  equal to the reciprocal of the largest unit cost in the kit.

2. Then, for each item  $j$ , they found the  $S_j$  maximizing  $F_j(S_j) - \theta C_j S_j$  and then computed the kit investment.

3. They then varied  $\theta$  and repeated steps 1 and 2.

It must be noted that even though all of these procedures have their good and bad points, they are all approximations. This includes the approach taken by the researcher.

#### Daily Demand Rate

In order to perform the marginal aid technique, it was necessary to calculate many data items such as the daily demand rate. The daily demand rate can and usually will exhibit a wide range of values from base to base. Obviously, those bases with more aircraft and/or large flying programs, would have an increased demand rate. The majority of the data was provided by AFLC/LORRA and is based on the D041 report. The D041 data base contains a data element which represents the demand rate per hundred flying hours. This data element is an exponential smoothing of information collected for the preceding two year period. Thus,  $\lambda$  can be found for a representative period. A general form for computing  $\Gamma$  (Daily Demand) is:

$$\Gamma_f = \text{ODP} \times \text{TDR}$$

where ODP = one day flying program (flying hours per day in hundreds)

and TDR = total demand rate (demands per day in hundreds)

ODP and TDR can be found in the D041 data base and can be used to represent failures per installed program hour for a single item. The quantity per application should be easily recognizable and included. Also, not all of the items are used on 100% of the fleet. To make these adjustments, merely perform the following:

$$\Gamma = \Gamma_f \times QPA \times PA$$

where QPA = quantity per application

PA = percent of fleet application of part i

Since total demand is a rate, it depends only on the number of flying hours and does not depend on the number of aircraft at the base. This computation can be used for deriving average total, base, and depot demands by simply using the appropriate demand rate.

#### Base Stocking Levels

Actual stock levels could not be obtained for a representative base; however, base stocking policy and all the necessary data was available to estimate its value. This was done by estimating the daily demand rate during peace and then adding a safety factor. This produces equation 2 in its expanded form which is:

$$L = RCQ + O\&STQ + SLQ$$

with  $RCQ = ODPP \times BRRP \times BRCDP \times QPA \times PA$

$OSTQ = ODPP \times DDRP \times O\&STP \times QPA \times PA$

and  $SLQ = \sqrt{3(RCQ + O\&STQ)}$

where  $ODPP =$  one day flying program in peace

$BRRP =$  base repair rate in peace

$BRCDP =$  base repair cycle days in peace

$QPA =$  quantity per application

$PA =$  percent application

and  $DDRP =$  depot demand rate in peace

All levels were rounded to the nearest integer. This stock level was needed in order to establish the limits in the cumulative Poisson distribution in equation 5.

#### Time Period of Interest

The time period of interest had to be calculated using the methods outlined in Chapter 3. However, in order to utilize the computer, a variation in computing depot delay had to be made. Recall,

$$\text{Depot Delay} = \sum_{X > S_0} (X - S_0) p(X | \lambda_0 T) / \lambda_0$$

Unfortunately, the computer will not sum to infinity, so the following equivalent equation was used:

$$\text{Depot Delay} = \frac{1}{\lambda_0} \left[ \lambda_0 T - \sum_{X=0}^{S_0} X p(X | \lambda_0 T) - S_0 + S_0 \sum_{X=0}^{S_0} p(X | \lambda_0 T) \right]$$

where  $\lambda_o$  = daily depot demand rate

$T$  = depot repair cycle time

and  $S_o$  = depot stock level

Thus, delays encountered due to stockouts at the depot have been accounted for by incorporating this procedure.

The time period of interest,  $G$ , was then computed as:

$$G = (O\&STW + DD) \times (1 - RTS) + (RTS \times BRCDW)$$

with all times those expected during war.

#### Automated Implementation

By using all of the data provided by AFLC/XRS, and AFLC/LORRA, the probabilities could be computed for any of the considered items. Refer to Figure 2 for a flow diagram of the system which implements the methodology. The system begins with raw data which is used to calculate directly the base stock level, the demand on the system, the computed time period of interest, the present BLSS kit, and the cumulative probabilities of any particular item. Stock level is used as an input into the time period of interest computation as well as the probabilities for each item. The values for time period of interest are used in the main program to calculate each individual item's probabilities and  $\lambda_s$ . These calculations must be done for each item considered to be a part of the BLSS kit. The result is a matrix of  $\lambda_s$  reflecting the marginal aid contributed by adding one more unit of each particular

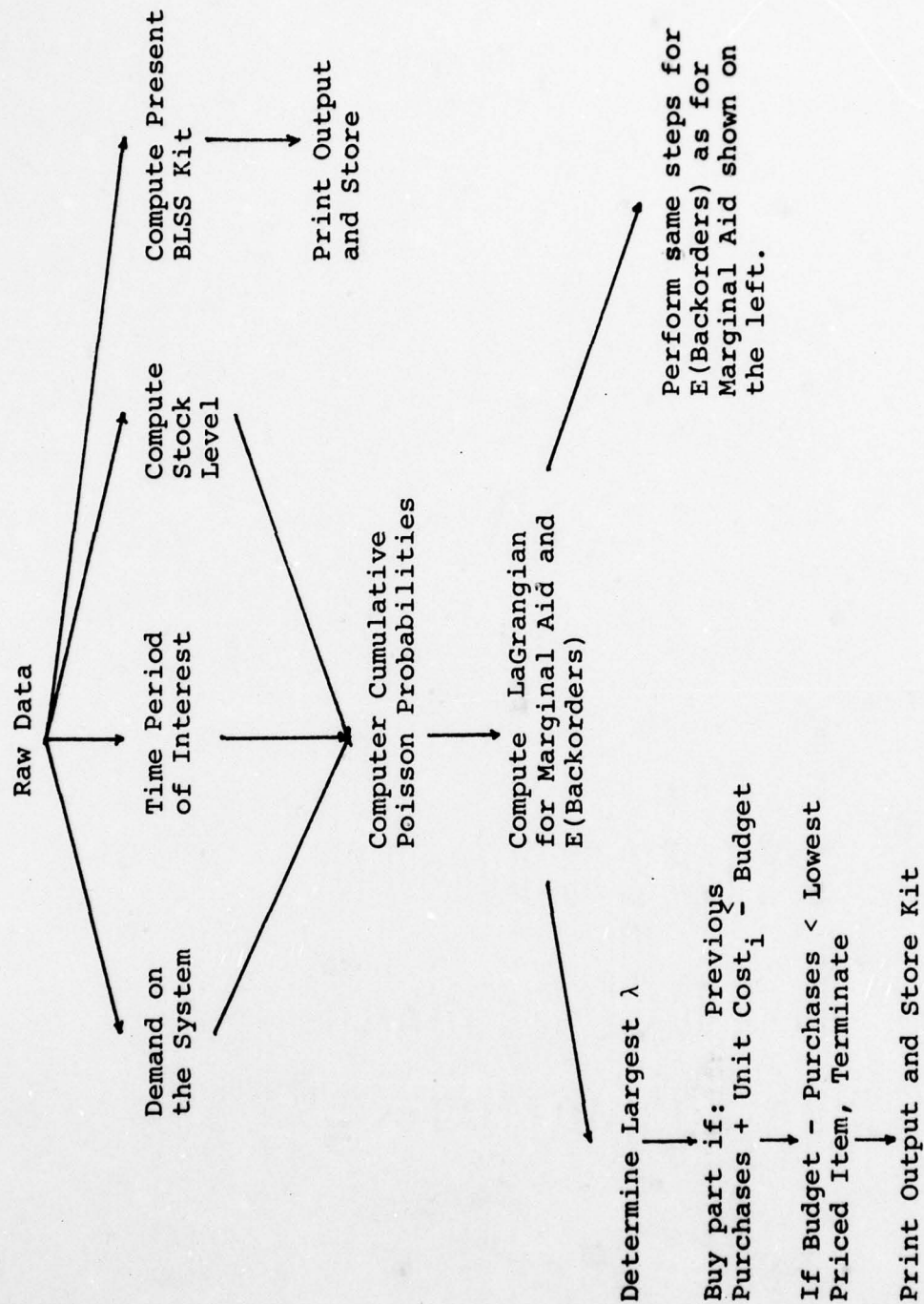


Figure 2. Flow Diagram of Automated Implementation

item with each item occupying a column of the matrix. The algorithm then searches the matrix for the largest  $\lambda$  and purchases that respective part if its monetary value added to those of items already purchased does not exceed the budget. The result is a BLSS kit made up of those items of the largest  $\lambda$ s which could enter a fixed budget kit. A number of kits were constructed which maximized the probability of Y or fewer aircraft downed. These kits were then stored for evaluation purposes.

#### Evaluating the BLSS Kits

In order to evaluate the kits constructed, the cumulative density function, identified by equation 4, was used to evaluate each kit in order to find the probability of Y or fewer downed aircraft for different Y values. Refer to Figure 3 for a flow chart depicting the system to evaluate the kits.

#### Data

Data was provided by AFLC/LORRA and AFLC/XRS. These organizations provided the following data: stock numbers, order and ship times in peace and war, one day flying programs in peace and war, quantity per application, depot demand rates in peace and war, base repair cycle days in peace and war, base repair rates in peace and war, depot repair cycle days, unit price, and percentage of application. The data were all expressed as worldwide averages. It should be mentioned that order and ship times, depot

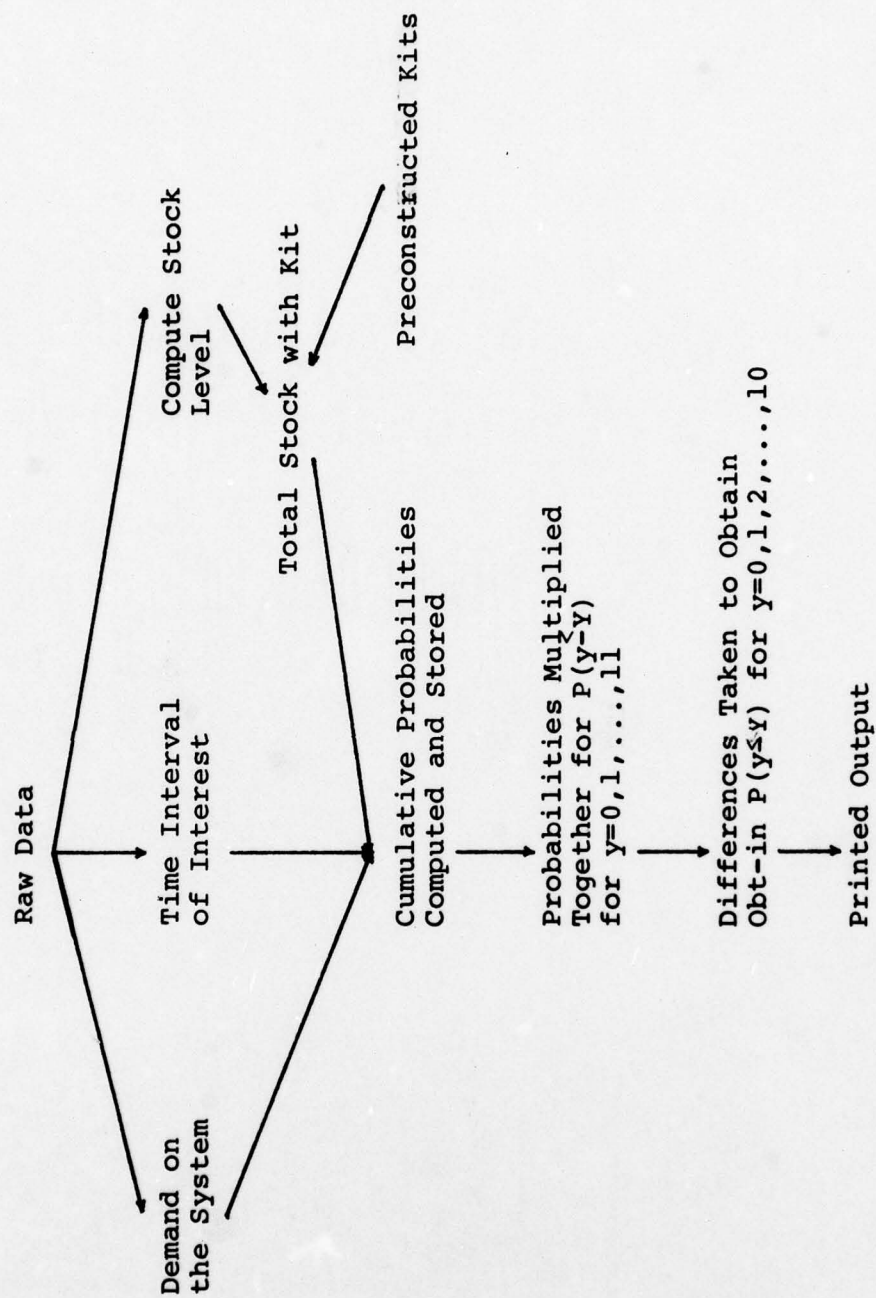


Figure 3. Flow Chart for Evaluation System

demand rates, base repair cycle days, base repair rates, and depot repair cycle days were the same for peace as in war because no methodology or data has been developed or collected which would produce what would be termed representative information.

#### Accuracy

Because of the probabilities and the mathematical computations that were performed in the computer algorithm accuracy became a very important factor. In order to minimize roundoff errors and to maintain accuracy through as many digits as possible, all probabilities and manipulations involving the probabilities were performed with double precision. Also, the researcher used his own algorithm to compute the probabilities because it compared well in accuracy with a library subroutine and was more consistent. Therefore, accuracy is not believed to be a problem since the algorithm chooses parts to purchase with at least 12 digits of accuracy.

## V. Results

### Introduction

In order to demonstrate the researcher's technique described in the previous chapter, BLSS kits were constructed using the present BLSS computational method, the proposed BLSS methodology, the minimization of backorders technique, and the marginal aid approach. To perform this demonstration, fifty F-15 data items of average demand rates were used.

### Results

The kit constructed by the present method is shown in Figure 3. The items are listed by increasing stock number and reflect the quantity of each item plus the total cost for that quantity. All items which are not purchased have a demand which is less than one-half and is rounded down. This method does not consider cost as a buy criterion. The total cost of this BLSS is \$45,138. Note that only 54% of the available items actually reflect additional WRM buys.

The kit constructed by the expected backorders (BO) technique is shown in Figure 4. This kit was constructed using a \$50,000 budget. The items are not listed as before, but by the way in which they were chosen for purchase and inclusion in the kit. Again the quantity is the number purchased and the cost is the total for the respective quantity.

PART NUMBER	QUANTITY	COST
1095000255657	1	1828.00
1270001382638	1	1407.00
1270001382639	1	3477.00
1270001385943	1	2123.00
1270002877224	1	2413.00
1270002877251	0	0.00
1270003680446	1	2540.00
1270003992829	1	700.00
1270003992830	1	600.00
1270005304434	3	1350.00
1270005304447	1	1900.00
1270005462568	2	4300.00
1270010032060	2	2860.00
1270010037476	1	1200.00
1270010129255	2	2680.00
1270010469884	3	120.00
1280001386186	1	500.00
1280001386208	0	0.00
1280003023922	0	0.00
1280003866913	0	0.00
1280003866936	0	0.00
1280005043715	1	1825.00
1280005043716	1	1900.00
1280005043717	1	2345.00
1280005043720	1	2265.00
1280005160987	0	0.00
1280005319101	0	0.00
1280010091180	0	0.00
1280010120446	0	0.00
1280010120447	0	0.00
1280010120449	0	0.00
1280010120450	0	0.00
1280010120457	0	0.00
1280010164701	0	0.00
1280010219488	1	1495.00
1280010219489	0	0.00
1280010219490	1	1040.00
1280010219491	0	0.00
1280010219492	1	640.00
1280010219493	0	0.00
1280010219538	0	0.00
1280010219539	0	0.00
1280010220292	0	0.00
1280010220293	0	0.00
1280010220295	1	2430.00
1280010220296	1	40.00
1280010220297	1	1130.00
1280010220300	0	0.00
1280010220319	1	30.00
1280010220751	0	0.00

Figure 3. BLSS Using Present Method

PART NUMBER	QUANTITY	COST
1280010220751	8	32.00
1270010469884	6	240.00
1280010220300	3	375.00
1280010220296	3	120.00
1270005304434	6	2700.00
1280010120449	2	180.00
1270003992830	4	2400.00
1280010220319	2	60.00
1280001386208	2	700.00
1280010220292	1	465.00
1270003992829	2	1400.00
1280010120450	1	275.00
1270010129255	3	4020.00
1270010037476	2	2400.00
1280010219491	1	920.00
1280010091180	1	1270.00
1280003866913	1	825.00
1270005462568	2	4300.00
1280001386186	1	500.00
1280010219539	1	780.00
1280010219489	1	1120.00
1280005319101	1	825.00
1280003023922	1	750.00
1280010219530	1	1390.00
1280005043717	1	2345.00
1280010120446	1	1850.00
1270005304447	1	1990.00
1280005043716	1	1900.00
1270002077251	1	2050.00
1280010220293	1	1020.00
1270010032060	1	1430.00
1280010164701	1	1270.00
1280010120457	1	980.00
1270001382638	1	1407.00

THE MONEY SPENT WAS 44999.00

Figure 4. BLSS Using Expected Backorders

The kits constructed by the marginal aid approach are shown in Figures 5 through 9. The kits were constructed so as to maximize the probability of no downed aircraft, the probability of one or zero downed aircraft, the probability of two or fewer downed aircraft, the probability of three or fewer downed aircraft, and the probability of four or fewer downed aircraft. The items listed are shown in the order in which they were chosen with quantity and cost displayed as previously. It appears that as the number of downed aircraft increases, as expected, the purchasing of parts changes. The purchasing shifts away from the low cost items and toward the middle and high cost items with higher demands. With this shift, the total number of different types of parts decreases.

It should be noted that an objective function was maximized subject to a single constraint by using a marginal analysis technique. This iterative technique chooses items to purchase that would produce the highest benefit with respect to the investment required. Since budget was used as a hard constraint, this method purchased items in the order chosen until the sum of purchases exceeded the budget. When that occurred, the last item selected was eliminated and the next best item chosen for purchase provided it did not cause purchases to exceed the budget. This process continued until the difference between the sum of the purchases and the budget was less than the value of the lowest dollar valued item under consideration.

NUMBER DOWNED AIRCRAFT IS 0

PART NUMBER	QUANTITY	COST
1280010220751	9	36.00
1270010469884	6	240.00
1280010220300	3	375.00
1280010220296	2	80.00
1280010120449	2	180.00
1270005304434	6	2700.00
1280010220319	2	60.00
1270003992830	4	2400.00
1280001386208	2	700.00
1280010220292	1	465.00
1280010120450	1	275.00
1270003992829	2	1400.00
1280010219491	1	920.00
1270010037476	2	2400.00
1270010129255	2	2600.00
1280010091180	1	1270.00
1280003866913	1	825.00
1280010219539	1	780.00
1280010219489	1	1120.00
1270005462568	2	4300.00
1280001386186	1	500.00
1280005319101	1	825.00
1280003023922	1	750.00
1280010219538	1	1390.00
1280010120446	1	1850.00
1270002877251	1	2050.00
1280010220293	1	1820.00
1280005043717	1	2345.00
1270005304447	1	1900.00
1280005043716	1	1900.00
1280010164701	1	1270.00
1280010120457	1	980.00
1280003866936	1	1375.00
1270010032060	1	1430.00
1270001382638	1	1407.00

THE MONEY SPENT WAS 44998.00

Figure 5. Marginal Aid Kit,  $P(y \leq 0)$

NUMBER DOWNED AIRCRAFT IS 1

PART NUMBER	QUANTITY	COST
1280010220751	4	16.00
1270010469884	7	280.00
1270005304434	6	2700.00
1280010220300	2	250.00
1270003992830	4	2400.00
1280010220296	3	120.00
1270010129255	3	4020.00
1270010037476	2	2400.00
1270003992829	2	1400.00
1270005462568	2	4300.00
1280001386208	1	350.00
1280010120449	1	90.00
1280010220292	1	465.00
1280010220319	2	60.00
1280010219491	1	920.00
1280005043717	1	2345.00
1280010091180	1	1270.00
1270005304447	1	1900.00
1280005043716	1	1900.00
1270010032060	1	1430.00
1280001386186	1	500.00
1280010120446	1	1850.00
1270002877251	1	2050.00
1280010219489	1	1120.00
1270003680446	1	2540.00
1280003066913	1	825.00
1280010120450	1	275.00
1280010219538	1	1390.00
1280010220293	1	1020.00
1270001382638	1	1407.00
1280005043715	1	1025.00
1280010219539	1	700.00

THE MONEY SPENT WAS 44998.00

Figure 6. Marginal Aid Kit,  $P(y \leq 1)$

NUMBER DOWNED AIRCRAFT IS 2

PART NUMBER	QUANTITY	COST
1280010220751	5	20.00
1270010469884	6	240.00
1270005304434	8	3600.00
1270003992830	4	2400.00
1270010129255	4	5360.00
1280010220300	3	375.00
1270010037476	3	3600.00
1270005462568	3	6450.00
1270003992829	2	1400.00
1280010220296	2	80.00
1280005043717	2	4690.00
1270005304447	1	1900.00
1280005043716	1	1900.00
1270010032060	1	1430.00
1280001386209	1	350.00
1280010219491	1	920.00
1270003680446	1	2540.00
1280010220292	1	465.00
1280010091180	1	1270.00
1280001386186	1	500.00
1280005043715	1	1825.00
1280010120446	1	1850.00
1270001382638	1	1407.00
1280010220319	2	60.00
1280010120449	1	90.00
1280010120450	1	275.00

THE MONEY SPENT WAS 44997.00

Figure 7. Marginal Aid Kit,  $P(y \leq 2)$

NUMBER DOWNED AIRCRAFT IS 3

PART NUMBER	QUANTITY	COST
1270010469884	7	280.00
1270005304434	8	3600.00
1280010220751	4	16.00
1270003992830	4	2400.00
1270010129255	5	6700.00
1270010037476	3	3600.00
1270005462568	3	6450.00
1270003992829	2	1400.00
1280010220300	2	250.00
1280005043717	2	4690.00
1270005304447	1	1900.00
1280005043716	1	1900.00
1270010032060	2	2800.00
1280010220296	2	80.00
1270003680446	1	2540.00
1280010219491	1	920.00
1280005043715	1	1825.00
1280010091180	1	1270.00
1280001386208	1	350.00
1270001382638	1	1407.00
1280001386186	1	500.00
1280010220319	2	60.00

THE MONEY SPENT WAS 44998.00

Figure 8. Marginal Aid Kit,  $P(y \leq 3)$

NUMBER DOWNED AIRCRAFT IS 4

PART NUMBER	QUANTITY	COST
1270005304434	8	3600.00
1270010469884	7	280.00
1270003992830	5	3000.00
1270010129255	5	6700.00
1280010220751	10	40.00
1270005462568	4	8600.00
1270010037476	3	3600.00
1280005043717	2	4690.00
1270003992829	2	1400.00
1270010032060	2	2860.00
1270005304447	2	3800.00
1280005043716	1	1900.00
1280010220300	1	125.00
1270003680446	1	2540.00
1280010220296	1	40.00
1280005043715	1	1825.00

THE MONEY SPENT WAS 45000.00

(a)

NUMBER DOWNED AIRCRAFT IS 5

PART NUMBER	QUANTITY	COST
1270005304434	9	4050.00
1270010469884	7	280.00
1270003992830	5	3000.00
1270010129255	6	8040.00
1270005462568	4	8600.00
1270010037476	3	3600.00
1280010220751	8	32.00
1280005043717	2	4690.00
1270003992829	2	1400.00
1270010032060	2	2860.00
1270005304447	2	3800.00
1280005043716	1	1900.00
1270003680446	1	2540.00
1280010220300	1	125.00
1280010220296	2	80.00

THE MONEY SPENT WAS 44997.00

(b)

Figure 9. Marginal Aid Kits  
(a)  $P(y=4)$ ; (b)  $P(y=5)$

Consequently, this method is just an approximation unless no balking were to occur and the difference between purchases and the budget was lower than the value of the lowest valued item. By making the budget a goal and not a hard constraint, the process would be exact in as much as the purchasing process would continue until just exceeding the budget with no balking. This process would be exact even if ties were encountered during the selections.

The evaluation of each kit was then performed with the results shown in Figures 10 and 11. Compared to the present method, the marginal aid methodology produces a kit which exceeds the performance of the present method in every way. In fact, all of the kits computed using the marginal aid technique outperform the present kit for each number of downed aircraft. AFLC/LORs proposed kit, which costs almost twice as much as the other kits shown, only outperforms the marginal aid kits by a slight margin. In a comparison with the present method, there is no question that the proposed method greatly exceeds the capability of the present method where capability is related to the probability of having more mission capable aircraft available.

In order to directly compare the proposed method and the marginal aid technique, the cost of the proposed kit was used as the budget in constructing marginal aid kits. The results of the evaluation of these kits is presented in Figure 12. This comparison looks just like that of the

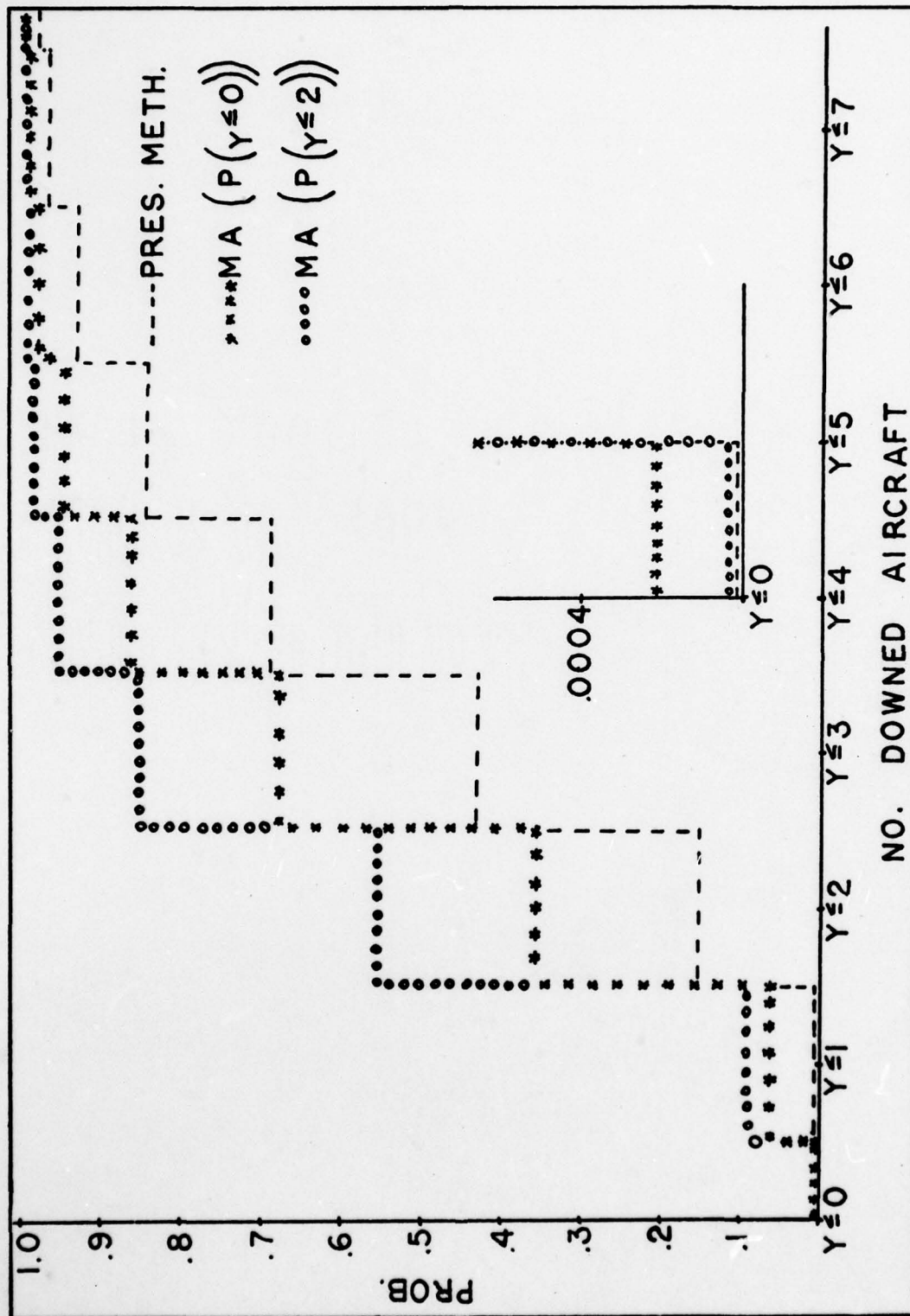


Figure 10. Marginal Aid vs. Present Method (\$45K Kits)

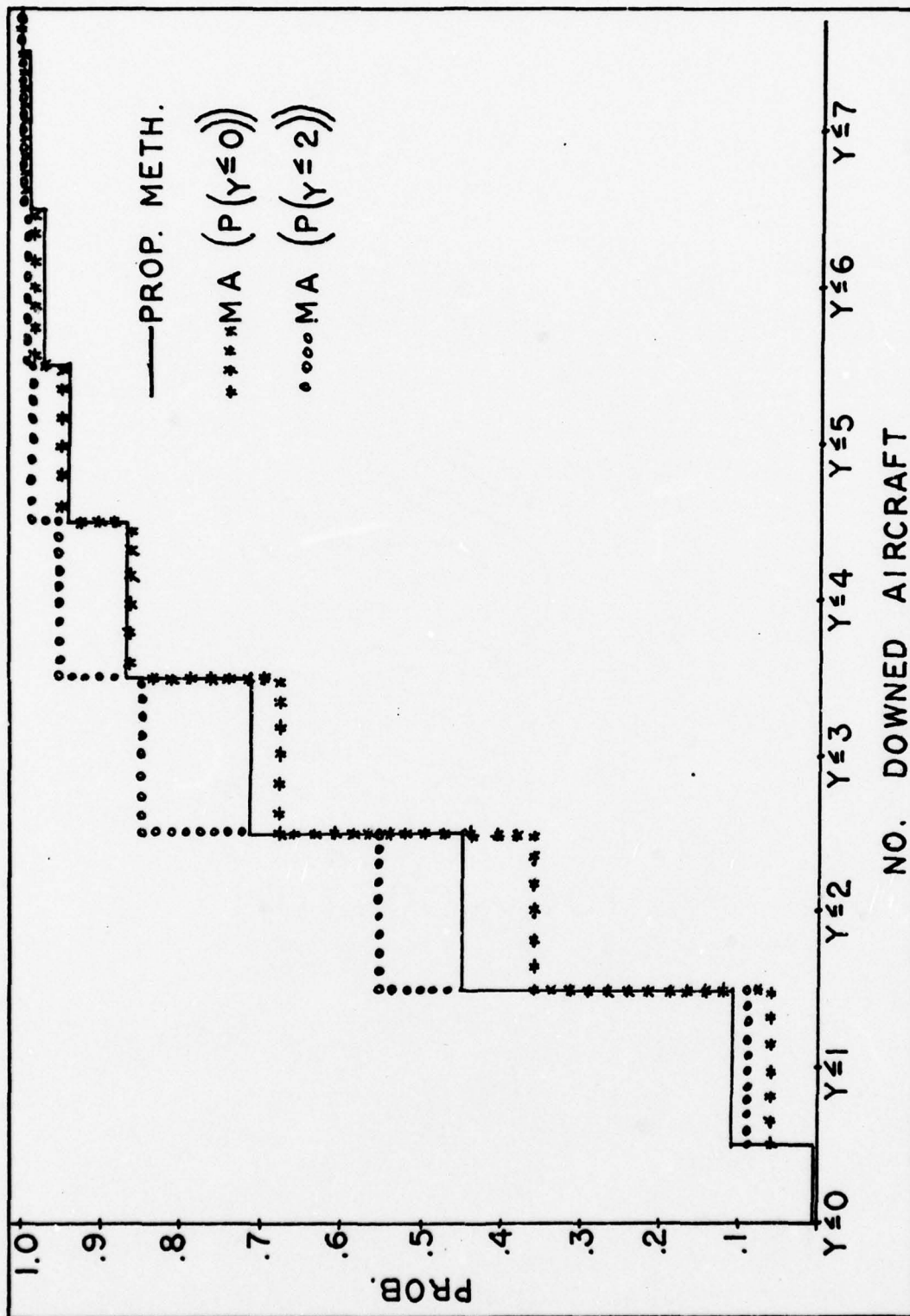


Figure 11. Marginal Aid (\$45K) vs. Proposed Method (\$80K)

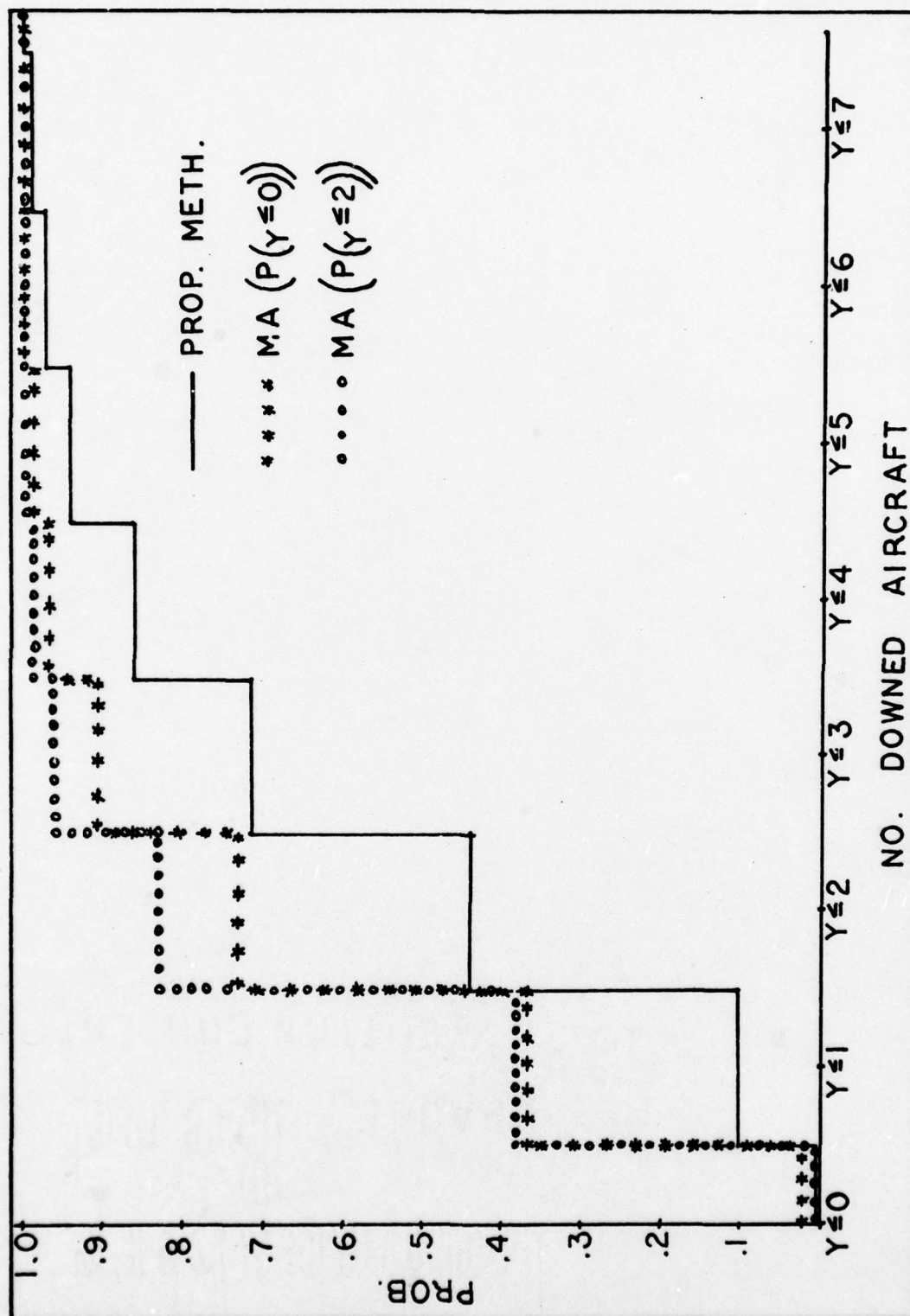


Figure 12. Marginal Aid vs. Proposed Method (\$80K Kits)

marginal aid approach to the present method (Fig 10). This makes sense, however, since the proposed method is the same as the present method except that buys are based on surge activity demands and not average demands as in the present methodology. Consequently, the marginal aid approach appears to exceed the capabilities of both the present and proposed methodologies when compared with the same budgets.

Included in the analysis was a comparison of the marginal aid approach with the minimization of expected backorders technique. Figure 13 shows that the two methods are not very different in capability for  $Y=0$ ; yet, the marginal aid kit is still better. In fact, all of the marginal aid kits are better when considering the criterion under which they were constructed. In other words, the kit for  $P(y \leq 1)$  exceeds the expected backorders kit for  $Y=1$ , as does the  $P(y \leq 2)$  kit for  $Y=2$ , and so on.

#### Data Problem

The reader may have questioned the magnitude of all of the probabilities displayed in Figures 10 through 13. This problem is partially because of a data point, depot stock level, that the researcher was unable to obtain for each part. As a result, an assumption of depot stock level had to be made. Initially, it was assumed to be equal to base stock level. This seemed a valid assumption for parts peculiar to the F-15 and pessimistic for common

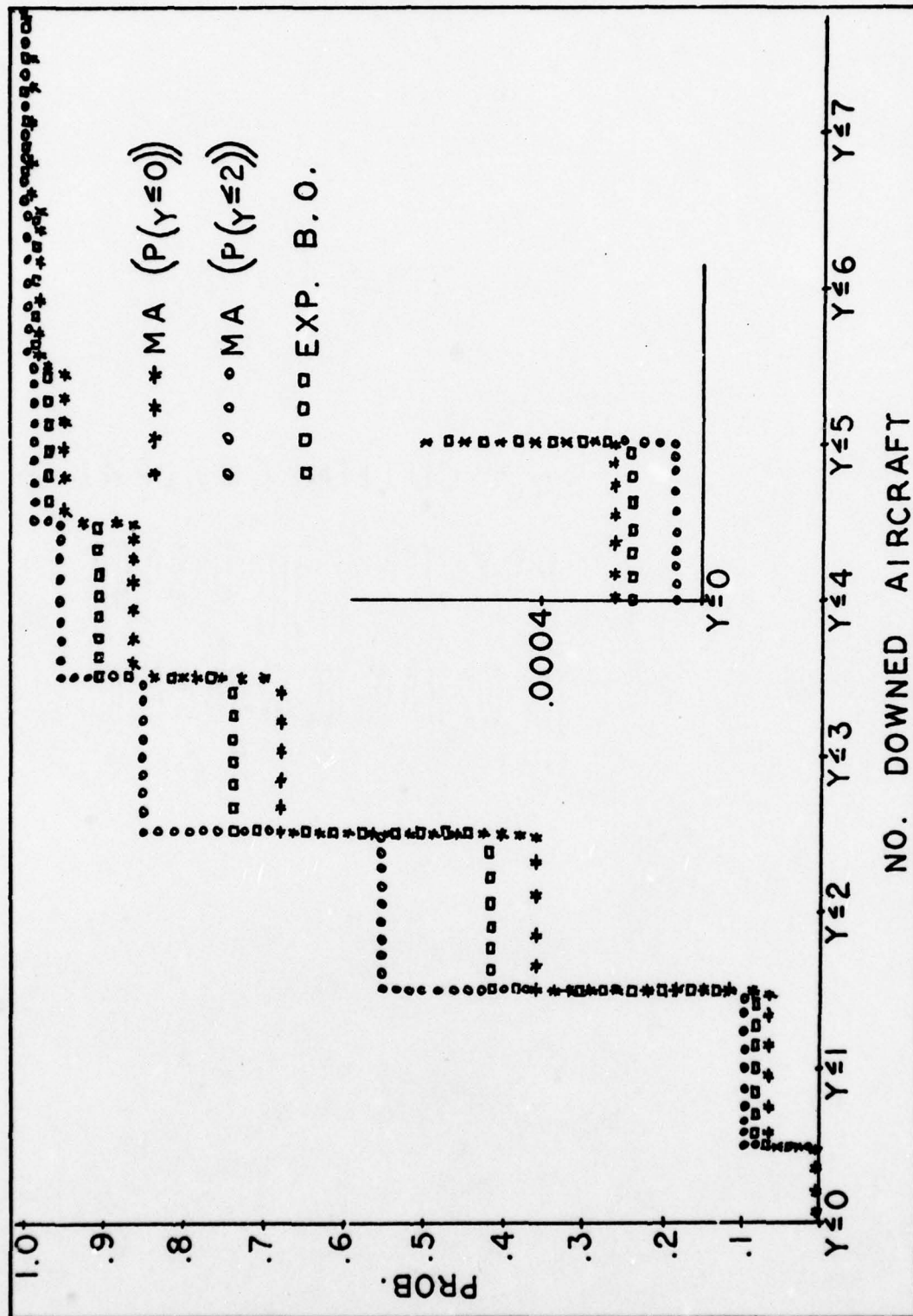


Figure 13. Marginal Aid vs. Expected Backorders (\$45K Kits)

parts. Consequently, the pessimistic assumption led to large depot delays which increased the time period of interest (G). As G increased, the overall demand, which is the parameter in the probability density function, increased, which produced a spread in the distribution of failures and resulted in lower probabilities for small stock levels. Thus, when all of the probabilities were multiplied together, the overall probability was reduced.

In order to ensure that analysis results did not change when the assumption changed, the depot stock level was multiplied by two and the analysis reaccomplished. The results are displayed in Figures 14 and 15. The effect of the change was to move probabilities to the left. As expected, the marginal aid kits maintained stochastic dominance over the present methodology and expected backorders kits where stochastic dominance refers to the larger cumulative probabilities associated with the marginal aid kits for the particular Y value of interest.

#### Recommendations

Because of the previous findings, it appears that the marginal aid technique is a viable method which could be used to improve BLSS kit construction by maximizing the probability of Y or fewer downed aircraft subject to a budget constraint. It makes no difference as to the situation under which the budget is operating. Given

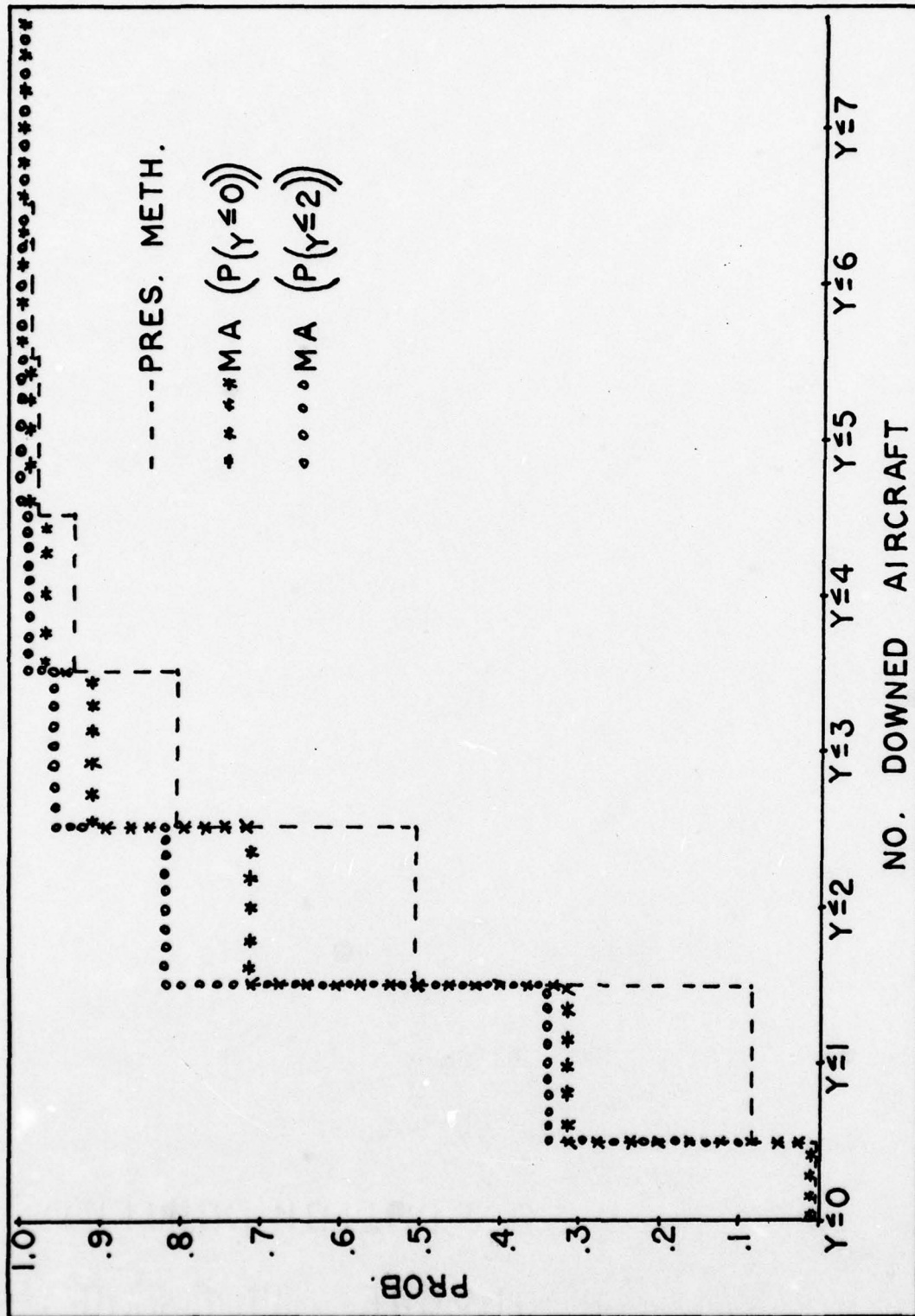
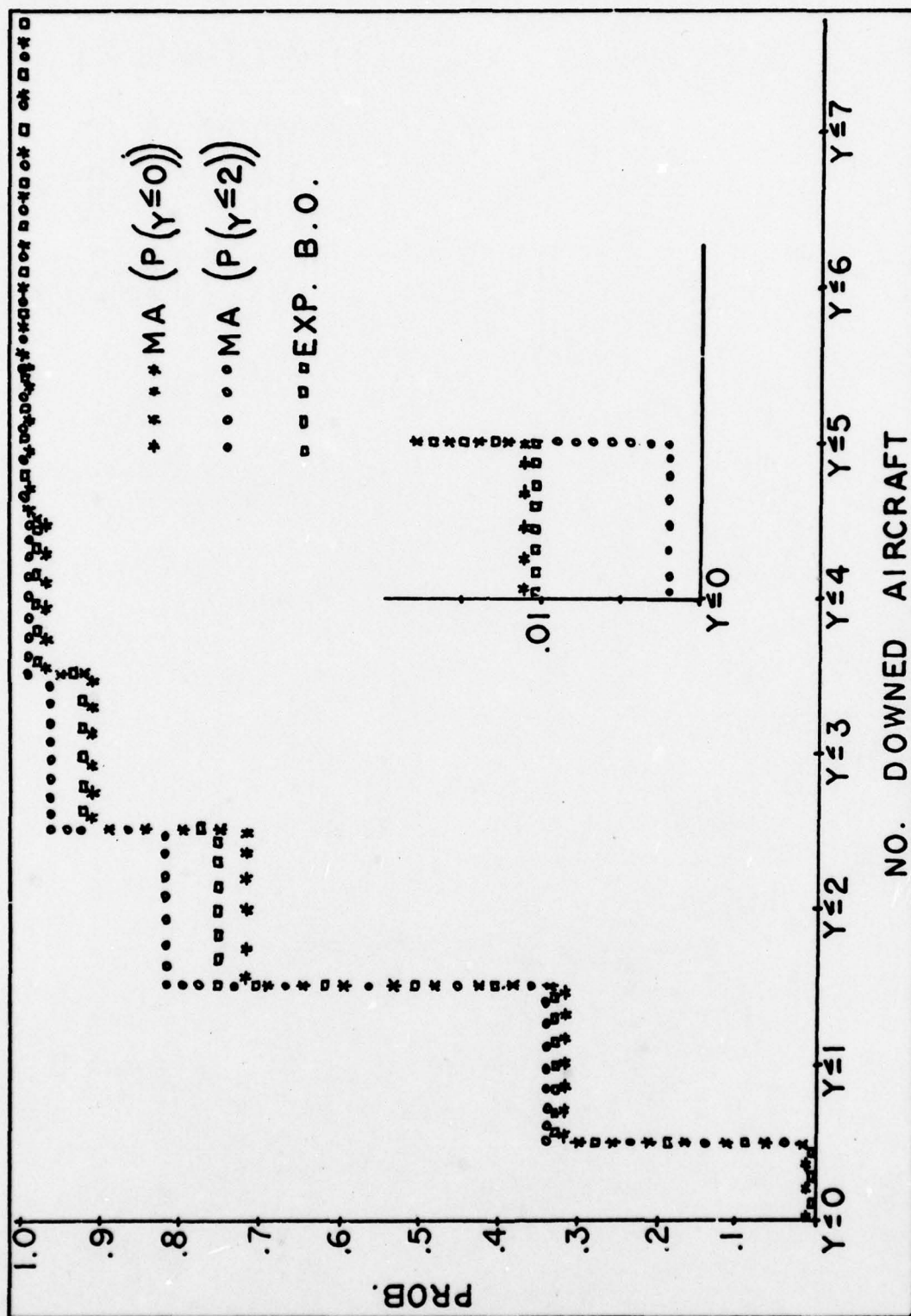


Figure 14. Marginal Aid vs. Present Method (Depot Stock=2xBase Stock)



**Figure 15. Marginal Aid vs. Expected Backorders (Depot Stock=2xBase Stock)**

any dollar amount, the marginal aid technique can be used to buy parts which will satisfy the marginal aid objective function and produce a better kit than any of the compared methodologies. Therefore, because of this technique's potential, it is recommended that:

1. The necessary depot stock level information be obtained,
2. The technique be completely validated by another demonstration using complete actual data for a full kit, and
3. Implementation of the technique be made by Air Force Logistics Command.

## VI. A Transient Look at the BLSS Kit

### Introduction

The preceding methodologies addressed by this thesis are static by nature and do not consider system dynamic effects. Since it is desired to describe or predict a kit which will maximize the probability of a certain number or fewer of downed aircraft, it would be of interest to know what variable changes affect the system over time. Only one part and a typical set of parameters need be modeled in order to see the general effects of parameter changes upon "on-hand" inventories, "in-process" inventories, etc.

### Methodology

In order to perform the desired investigation, a model using the DYNAMO system language was constructed (Appendix D-F). The model uses the following philosophies.

In normal peacetime operation, parts, upon failure, are removed from the aircraft and a requisition is sent to base supply for a replacement. If one is available, it is sent to base maintenance for installation on the deficient aircraft. Following removal of the failed part, a decision is made as to whether the failed item may be repaired locally or must be sent to the depot for repair. Those parts reparable at the base level are sent to base maintenance shops for repair. Following the base repair cycle time (BRST), the part will be automatically shipped back

to supply and put into the base inventory.

Those parts which cannot be repaired at the base level are shipped to the depot for repair. The depot's first action is to determine whether the part can be repaired or not. If the part is non-reparable, it is condemned and a request for a replacement is sent to the procurement function. Those parts which can be repaired are sent to the repair facility and following a depot repair cycle time (DRCT) are sent to depot inventory (DINV). When a requisition is received from a base, the depot fills the order from its own depot inventory. For this reason, all depot repairs go to depot inventory and then are shipped, if needed.

The model uses the following peacetime considerations:

- a. The fill rate reflects the state of base inventory (BINV); that is, the fill rate is the minimum of the size of the base inventory and the failures plus backorders.
- b. The procurement delay is accounted for by using a first order delay (exponential smoothing).
- c. It is assumed that 10 percent of those failures sent to the depot for repair are condemned.
- d. The desired base inventory is an average of total failures over a 15 day period multiplied by an inventory coverage of 15 days.
- e. The desired base backlog is an average of the number of failures to be repaired locally over

a 30 day period multiplied by the base repair cycle time.

- f. If there is a difference between the desired base backlog and the number of units in base repair (BR), the discrepancy will be an average made up over 5 consecutive days.
- g. Any difference between desired base inventory and actual base inventory will be made up over a period of 15 days.
- h. Production rates at base and depot are considered constant.
- i. The base workforce adjustment time (BWFAT), is considered constant.
- j. The failures to be repaired at depot are assumed to be nine-tenths of the failures shipped to the depot.
- k. As a failure occurs at a base, a requisition precedes the failed part to the depot. The depot ships an operational part upon receipt of the requisition if a part is available in depot inventory. Otherwise, the depot will ship a part when one becomes available through depot repair (DR) or procurement. An operational delay is used on all requisitioned parts if they are available as far as order and ship time is concerned.
- l. Depot and base inventories are not allowed to be negative.

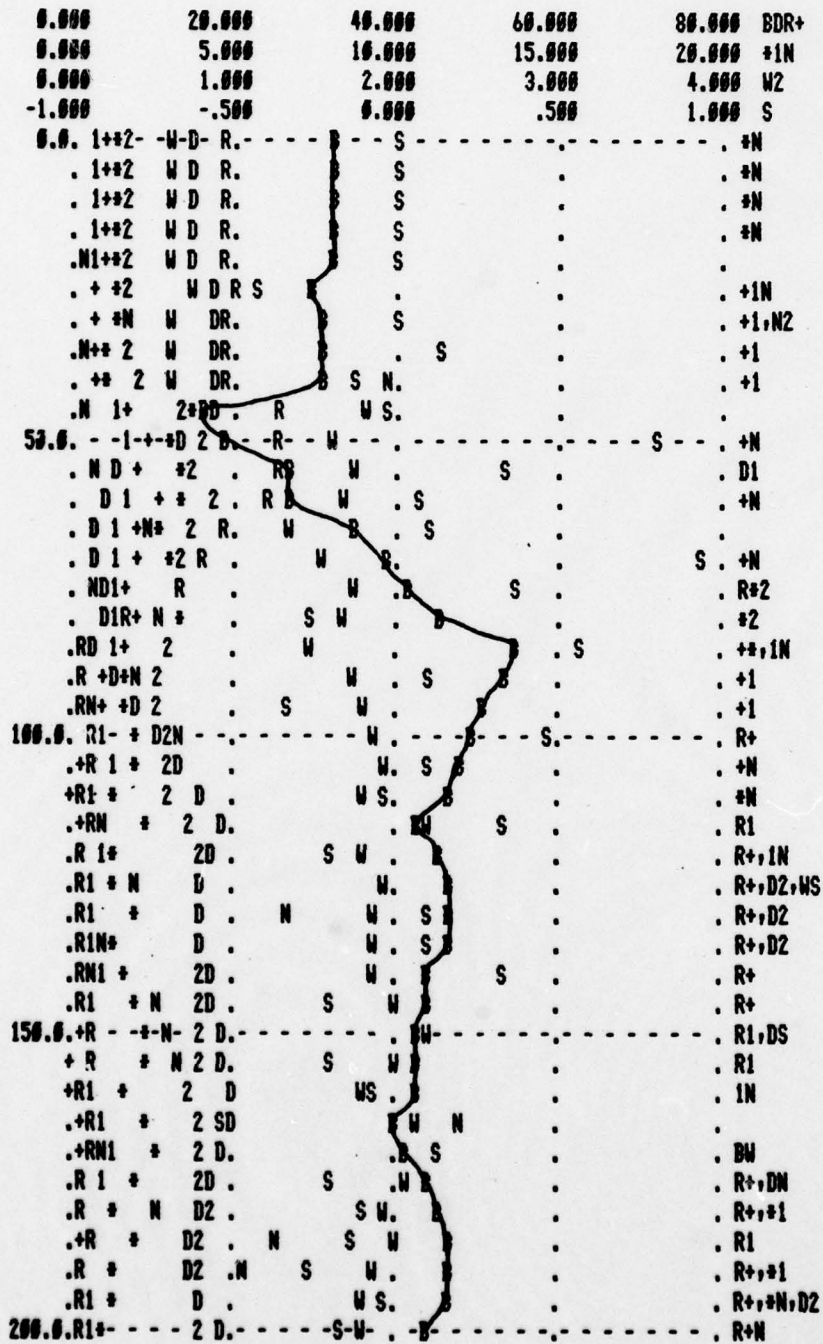
- m. The procurement delay to replace all condemnations is smoothed over a 50 day time frame.
- n. It is considered necessary to have a backlog at depot which is computed as an averaging of failures over 30 days.
- o. The desired depot workforce is a function of the failure rates and the difference between the desired backlog and the actual backlog.
- p. Desired shipping rate is not allowed to be negative and is positive only when a positive discrepancy exists between desired base inventory and actual base inventory.

In running the model, war was assumed to begin at time 40 with a reduction in activity at time 60. The number of missions never returned to the peacetime level; however, war plans call for the number of missions to subside to a more sustained rate which they did at time 80. There are those who would compress this schedule slightly; however, this schedule allows for a small scale expansion for better display. A slight compression of the war scenario would only produce slightly higher peaks due to overshoots caused by higher accelerations in meeting demands.

### Results

The results of the model are shown on graphs such as Figure 16. This figure is a computer output representing the flow of the graphed variables over the time units

BINV=B DINV=D DR=R BR=+ DRR=+ BRR=1 FDR=N DWF=W BWF=2  
NBS=S



**Figure 16. Basic BLSS Model**

shown on the extreme left hand side of the graph. The graph should be read from top to bottom by finding the variable of interest and then connecting the code down the page. Each variable is represented by a symbol with the referenced variable shown in the key at the top of the page. In all of the graphs to be presented in this thesis, the following codes will be used:

- B - Base Inventory
- D - Depot Inventory
- R - Depot Repair (in-process)
- + - Base Repair (in-process)
- \* - Depot Repair Rate
- l - Base Repair Rate
- N - Failure Rate for Parts Sent to Depot for Repair
- W - Depot Workforce
- 2 - Base Work Force
- S - Number of Backorders

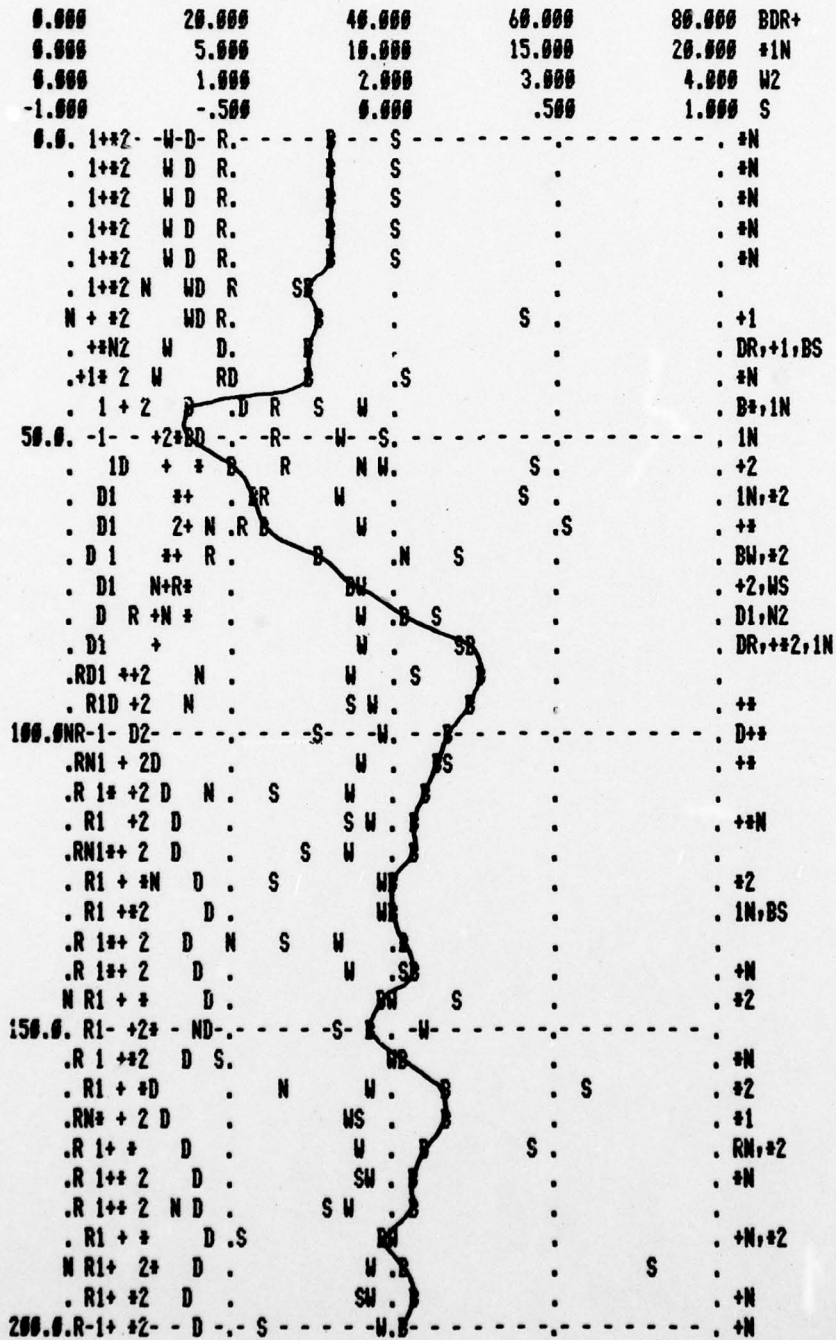
The scales are printed at the top of the graph with the applicable variables listed at the far right. Also on the far right, any variables which tie for graph position will be shown with only the first one on the right hand margin printed. All of the graphs presented were programmed to show a steady state equilibrium until time 20 when random noise was introduced. Simulated war was then introduced at time 40. Since base inventory is the primary variable of interest, it will be shown with a darkened line in all graphs.

The final model showed a depot inventory and base inventory which reacted exactly as anticipated when war began (Fig 16). The desired base inventory increased rapidly at the beginning of war due to an increase in failures and began to decrease slowly as the original surge diminished. The actual base inventory lagged behind desired, but eventually caught up by drawing down the depot inventory. As soon as the base inventory was close to desired, the depot inventory built up to its desired level. The levels then began to oscillate because of the noise in the system.

In order to examine the effects of base workforce adjustment time (BWFAT), its value was increased to 20, twice its original value (Fig 17). Both inventories behaved as before except they reached their peak values a little later because of the adjustment. The rates of change of the inventories did, however, appear to be slightly faster. The depot repair rate (DRR) picked up the need for help and produced faster than before. The peak base inventory was lower due to increased base repair inventories.

In order to examine the effects of depot workforce adjustment time (DWFAT), its value was increased from 3 to 10 days (Fig 18). This produced behavior very similar to that seen before except that the peaks were shifted later and the magnitude of the base inventory peak was slightly smaller with the depot inventory remaining low for a longer time. Again, as soon as the base inventory

BINV=B DINV=D DR=R BR=+ DRR=+ BRR=1 FDR=N DWF=W BWF=2  
NBS=S



**Figure 17. Change with BWFAT=20**

BINV=B DINV=D DR=R BR=+ DRR=+ BRR=1 FDR=N DWF=W BWF=2  
 NBS=S

0.000	20.000	40.000	60.000	80.000	BDR+
0.000	5.000	10.000	15.000	20.000	+1N
0.000	1.000	2.000	3.000	4.000	W2
-2.000	0.000	2.000	4.000	6.000	S
0.0.	1++2-	-W-D-	RS-		.+N
	. 1++2	W D	RS		.+N
	. 1++2	W D	RS		.+N
	. 1++2	W D	RS		.+N
	. 1++2	W D	RS		.RN
	N + +2	W	DRS		.+1
	. + +	N W	DRS		.+1,+2
	N + +2	W D R	S		.+1
	.+1 +2	WN	DRS		
	.N 1+	+2 D	B. WS	R	
50.0.	- D + - + -	-W-N-	R		D1,B2S
	. D 1 B + +	2.	S W	.R	.+N
	. D1 + +2		W	R	.1N
	. D1 + +2		S W	.R	.1N
	. D1 + +	S	NW	R	.B2
	.ND1+ +	S	W	R	.+2
	. D 1+	+N	SB	W R	.N2
	N D1+	+2	S.	W R R	
	.ND1+	+2	S.	W R B	
	. D + N +	S	.R		.+1,RW,+2
100.0.	D1- +2-	-S-R-W-			D+
	. D1N +2	R.S W			D+
	.+ 1 D+ 2R	.S WN			D+
	.+1N	DR2	S	W	.+N,D2
	.+1	R + D	S.	W	
	.+1 R N	+2 D S	W		
	.R 1 + N	2DS.	W		.R+
	+R1 +	N2 DS	W		
	.R 1 +	2 D.	N W		.R+,DS
	.R1 +	2 D S	W		.R+N
150.0.	R-1-+	-2 D.-	-S-	-W-	R+N
	.R1 N+	2 SD	W		.R+
	.+R1N +	2 SD	W		
	+R1 +N	2 S.D	W		
	.+R1 +	S2 D	W		.RN
	.R + N	2D.	W		.R+,+1,2S
	.+R1 +	2 D.	W		.+N,2S
	+ R	+ 2 D	W		.R1,+N,2S
	.R 1 + N	2D . S	W		.R+
	.+R1 +	D S.	W		.DN2
200.0.	+R - + N -	D S.-	-W.-		R1,D2

Figure 18. Change with DWFAT=10

reached its desired level, the depot inventory began to recover. Depot repair processing did increase significantly.

The NRTS rate was first increased from .7 to .9. The system did not change significantly; however, depot inventory was drawn down longer due to a larger in-process inventory. There was no effect on base inventory. Once depot inventory began to recover, it stabilized at a higher level.

NRTS was then decreased from .7 to .4 (Fig 19). As a result, base inventory was depleted as previously; however, base inventory climbed slower and peaked lower. Thus, in a surge, base inventory would exhibit a similar behavior since supply lines to the depots may not be open and the base may have to assume a larger role in repair if it is capable of doing so. The important points are (1) slower reactions, and (2) not being able to reach the peak level as before, thus producing less inventory coverage in the equilibrium position.

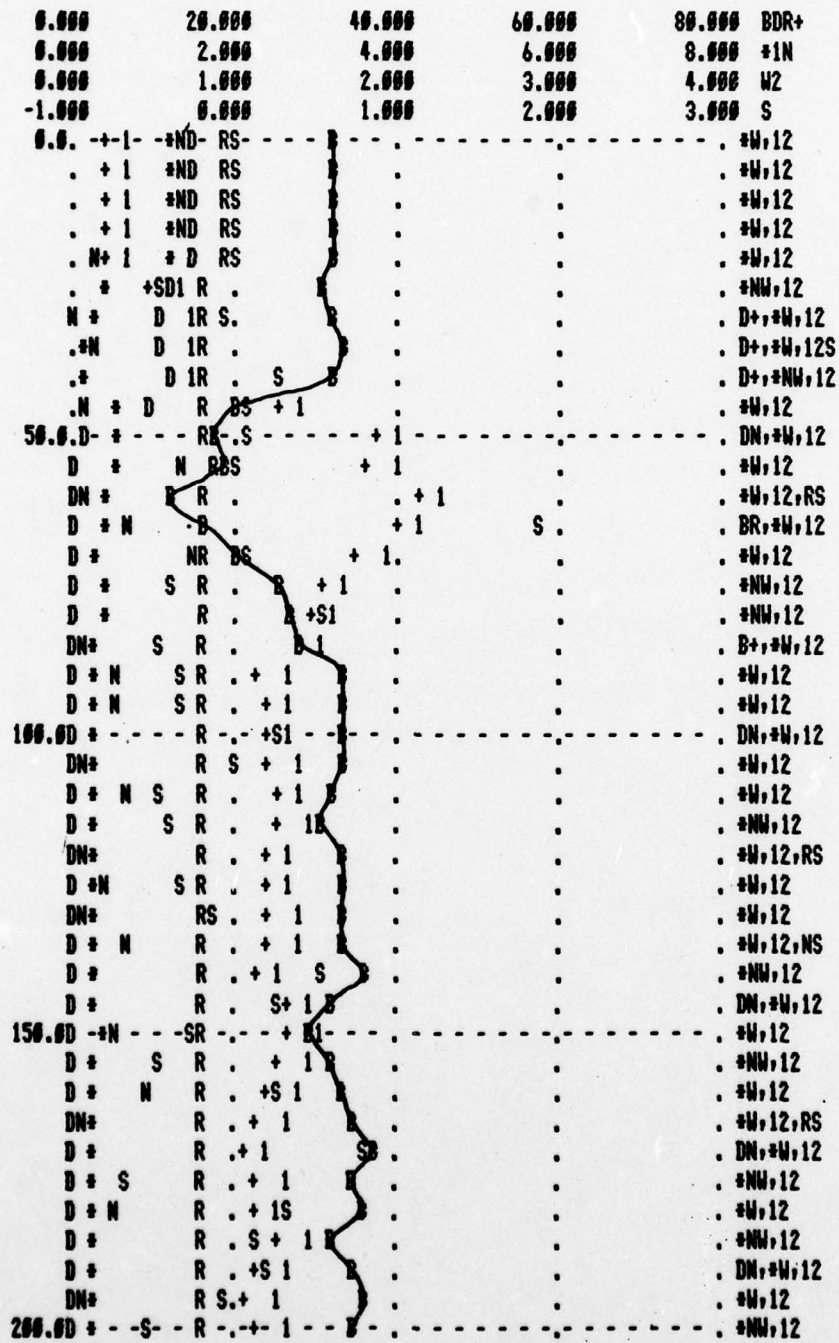
In order to see the effects of a virtual cut-off from the depot, NRTS was further reduced from .7 to .1 (Fig 20). This reduction implies that either supply lines have been drastically cut and/or the commander wants to repair everything for which he feels he has the capability. The results were the same as above only more drastic. The base inventory never peaked. It rose slowly and then began to oscillate due to fluctuations in the system. The

BINV=B DINV=D DR=R BR=+ DRR=+ BRR=1 FDR=N DMF=W DMF=2  
NBS=S

0.000	20.000	40.000	60.000	80.000	BDR+
0.000	2.000	4.000	6.000	8.000	*1N
0.000	.500	1.000	1.500	2.000	W2
-1.000	0.000	1.000	2.000	3.000	S
0.0.	+-1-	+ND-	RS-	W-	N2
.	+1	+ND	RS	W	N2
.	+1	+ND	RS	W	N2
.	+1	+ND	RS	W	N2
N	+1	+2D	RS	W	
.	++N1	WDRS.			R2
.	++	DR2N			*1,NW,RS
.	N++1	SDR .2			RN
.	++	1MD R .2			*N,BS
.	S D N R 1	W	2		R+,B*
50.0.	-DS-	-N-	R+-	1-	+-
.	D	S	R+	1	+-
.	D N	RS	R+	1	+-
.	D	S	*R	1	B+
ND	+	RS+	1		1W
.D	NS	*R+	1		
.D	*R	+	1N		BW
.D	N	S R+	+	1	BW
.D	N	R	+	1	1S
.D	R	+	1	NS	+-
100.0.	-D-	-R-	+	1-	+-,1S
.	D R	++1.			RN,++S
.R	D N	+1.	S		+-
.R	DN	+S	+1.		
.RN	*D	+1	S		
.R	*D	1	S.		D+N
.R	*D	S1			BW
.R N	D	++1.			
.R	*D	+1.	SN		
.R	D	+1.			*N,++S
150.0.	-R-	-ND-	+-	1-	BW
.R	D	+	+1	S	RN
.R	D	+	S1.		DN
.RN	D	+	+1.	S	BW
.R N	D	+	*1.		
.R	D	++1.	S		+N
.R	ND	+1.			D*,BW,++S
.R	D	+1	S.		D*,RN
.R N	*D	+1.	S		
.R	N	+D	+S1.		
200.0.	-R-	-D	+S1-		D*,RN

**Figure 19. Change with NRTS=.4**

BINV=B DINV=D DR=R BR=+ DRR=+ BRR=1 FDR=N DMF=W BMF=Z  
NBS=S



**Figure 20. Change with NRTS=.1**

equilibrium value was significantly lower than when NRTS was .7. In-process inventory at the base absorbed the stock which was no longer in "on-hand" inventory. It is interesting to note that even though NRTS decreased, the base was able to deplete all depot inventory since the resupply lines were not completely closed.

In addition to dropping NRTS, order and ship time was increased to see the effects of a degraded supply system (Fig 21). The result was a higher in-process inventory at the base, a depleted depot inventory, a spike in backorders, and approximately the same base inventory behavior.

The next variable to be investigated was depot repair cycle time (Fig 22). A doubling of DRCT from 15 to 30 days produced a base inventory with almost exactly the same behavior as before. Depot repair did increase significantly which raised depot inventory to a higher level since larger coverage was needed in war.

Base Repair Cycle Time was also increased, from 5 to 10 days (Fig 23). The results were not very significant except that depot inventory had to pick up the slack and it was held down longer with the final depot inventory slightly larger than previously.

### Conclusions

It appears that the system is much more sensitive to changes in DWFAT than in BWFAT. Also, depot repair appears

BINV=B DINV=D DR=R BR=+ DRR=\* BRR=1 FDR=N DWF=W BWF=2  
 NBS=S

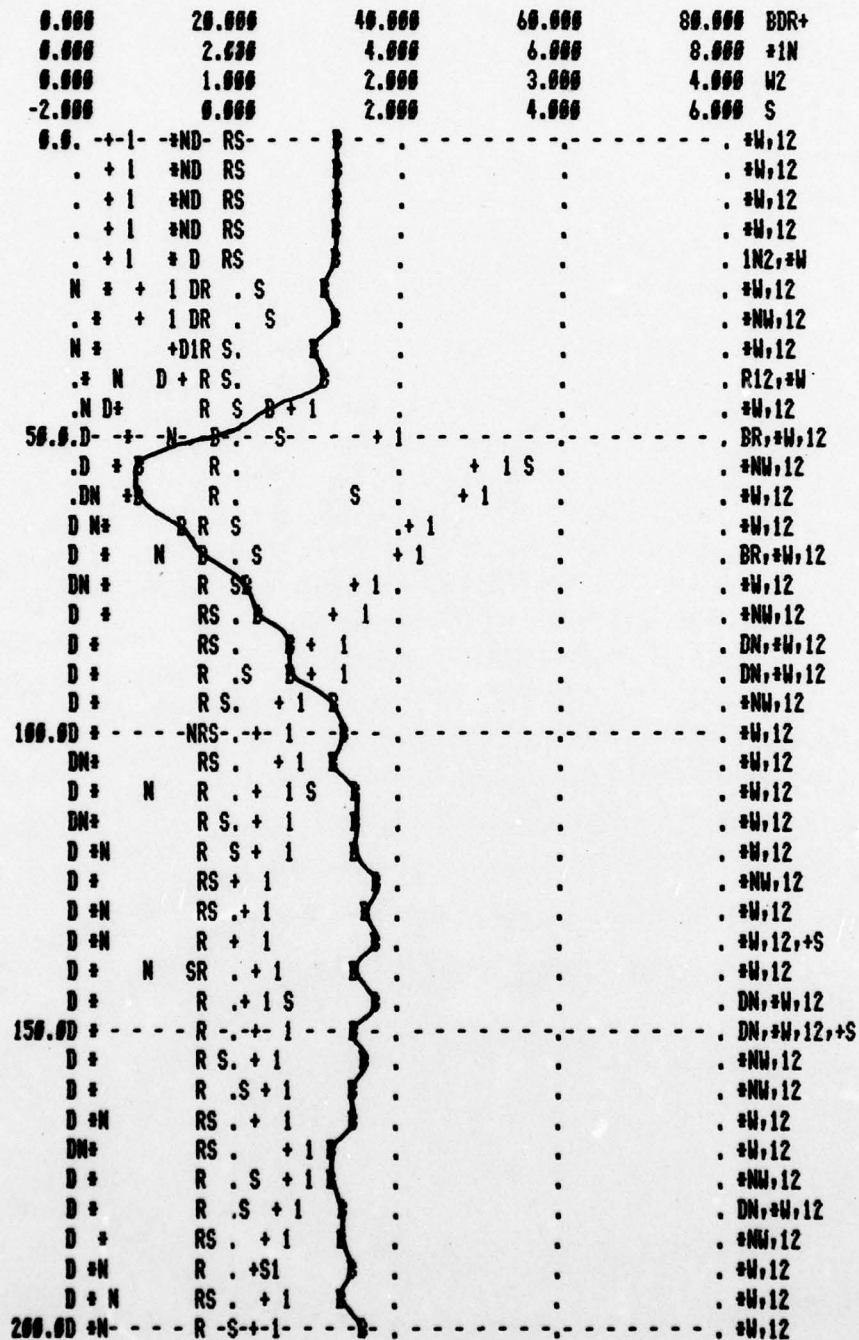
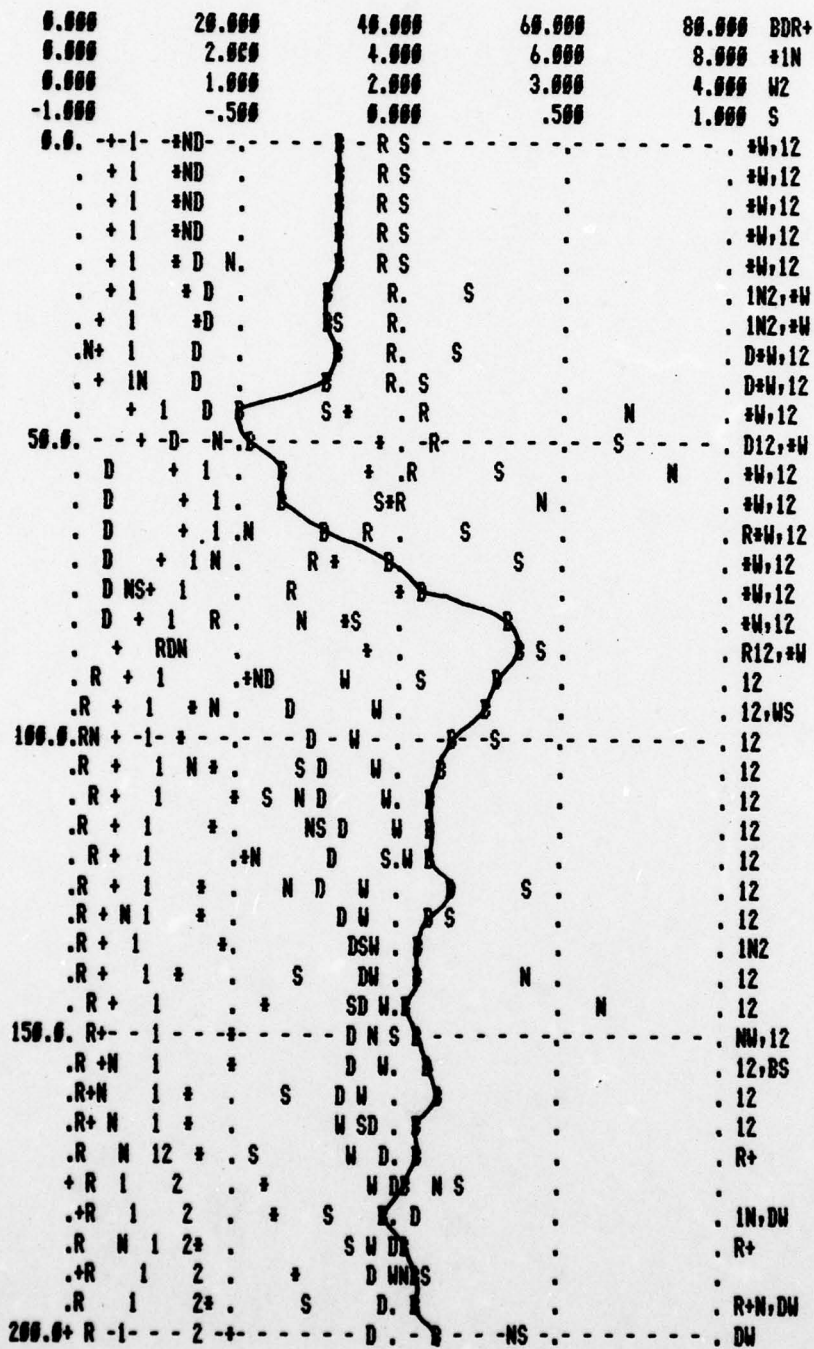


Figure 21. Changes with OST=30 and NRTS=.1

**NBS=S**



**Figure 22. Changes with DRCT=30**

BINV=B DINV=D DR=R BR=+ DRR=# BRR=1 FDR=N DWF=W BWF=2  
 NBS=S

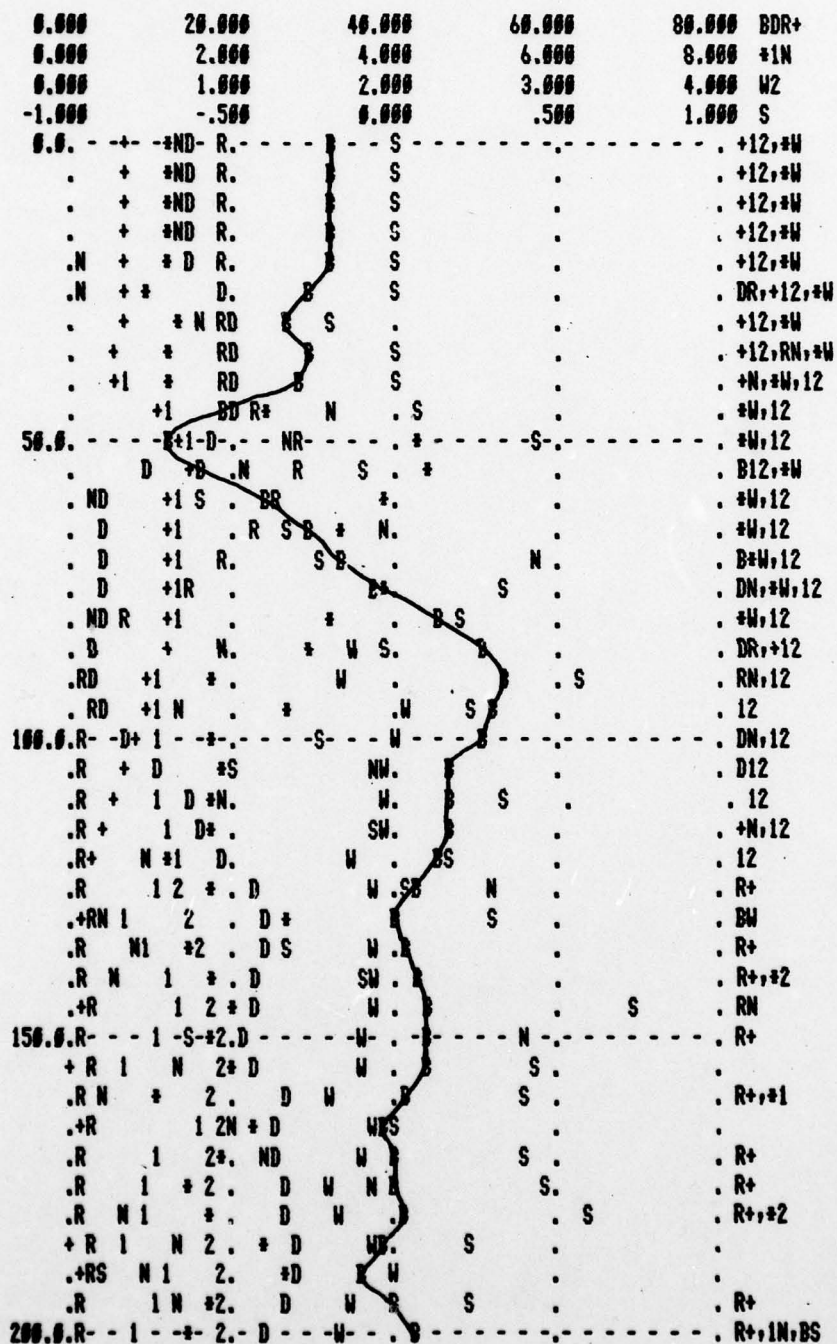


Figure 23. Change with BRCT=10

to be crucial to the system since all changes within the total system affect it. The major point in this analysis is, however, that reductions in NRTS can produce a higher base in-process inventory. This, in turn, reduces the base inventory which implies that the BLSS kit may be expected to provide more support than originally planned during BLSS construction. The BLSS cannot, however, since it would suffer from the same problem. A normal response to the increase in in-process inventory would be to increase the production output by working longer hours. This, however, might not be a fruitful option since the base is retaining items which it normally does not repair. This lack of experience in repair could result in no real change to the production rate even though longer hours are being worked.

There is a small amount of noise in the model due to the computational technique internal to DYNAMO. Consequently, the measurement of backorders produce a relative rather than an accurate response. Just the same, the model produces accurate information which can be used in policy comparisons. Also, by initializing the base inventory at the "authorized level" plus a BLSS kit, the model can be used to evaluate different BLSS kits. The only limitations to this would be the amount of computer time necessary in executing the model once for each part in the kit.

Consequently, the study of the model has provided

some insights into the environment in which the BLSS must operate, especially the importance of the role played by the pipeline to and from the depot. In case of war, both normal inventories and the BLSS kit would be subject to any pipeline changes. Thus, extra consideration of these factors should be made during BLSS construction and commanders should be made aware of the effects of any variable changes they might want to make.

## VII. Summary and Areas for Further Research

### Summary

This study has examined the construction of BLSS kits. At present, all of the existing and proposed methods do not attempt to optimize kit construction in any way. They only look at average demands or surge demands and do not consider costs in determining what parts and how many of each should be included in the kit. This led the researcher to the development of a cumulative density function for a certain number or fewer of downed aircraft for supply. An index was then developed which expresses the value of an additional item subject to its cost. Thus, an expression was developed which could be used to discriminate among parts in determining the items with the better return on investment.

The developed procedure was performed and BLSS kits constructed using a typical sample of 50 items for demonstration purposes only. The newly constructed kits were then compared with the present, proposed, and minimization of backorders methods. Comparison with equal dollar valued kits produced the conclusion that the kits constructed using the researcher's technique (marginal aid) were stochastically dominant over all the other compared methods. Thus, the further study and eventual implementation of the marginal aid technique by the Air Force Logistics Command is recommended.

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AN APPLICATION OF MARGINAL ANALYSIS TO BASE LEVEL SELF-SUFFICIE--ETC(U)  
DEC 78 T R BRIDGES

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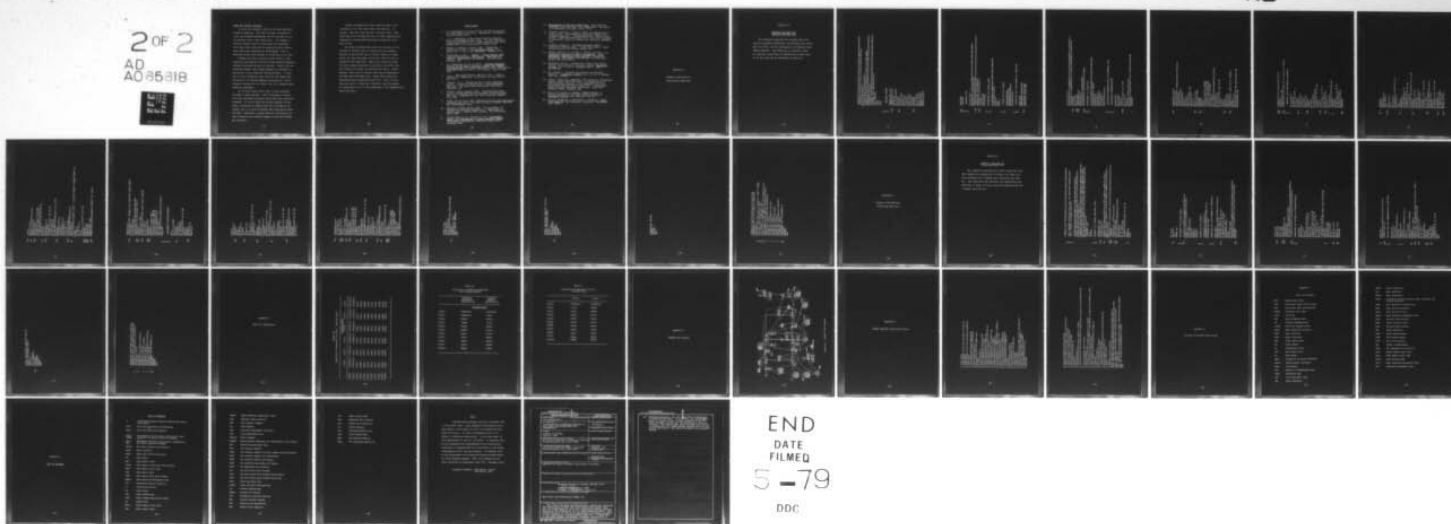
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### Areas for Further Research

As with all research, there are as many questions raised as answered. This work has been no exception since the developed methodology did not consider all of the possible events that could occur. For example, a breakout between LRUs and SRUs should be considered since many items which can be repaired locally require parts which may themselves be backordered. Thus, a grounding would occur because of an SRU and not an LRU.

Another area that requires further study is that concerning the manpower situation under which the marginal analysis technique may have to operate. Recall that the technique assumes that enough manpower is available to perform all of the required cannibalizations. If this were a false assumption, what would be the impact upon the BLSS kit of reduced manpower availability? Since manpower availability is finite, this is a concern which should be addressed.

All of the failure rates used in this study were the same in peace and war. This is because no studies have been performed previously which have been generally accepted. It is not known for certain whether failure rates (a function of flying time) will increase or decrease, but it is hard to believe that they would remain the same. Therefore, a study should be initiated to at least ascertain the relative change in failures between war and peace.

Another consideration which could be made is the inclusion of all EOQ items within the BLSS kit. At present, most EOQ items are part of bench stock. They could easily be incorporated into the BLSS computational technique to provide WRM protection through the early days of war.

Two other considerations which can be made are the pooling of similar units to reduce the total support dollars in war and the use of lateral supply of common parts, not only from base to base but from one unit to another at the same base. Many units which have BLSS kits are already stationed in positions from which they are likely to be close to potential war zones. Consequently, other like or similar units may be deployed to the same base with WRSK kits. These events should be considered when constructing both kits. Also, if more than one unit at a base has a BLSS kit, the kits should be constructed so as to take advantage of the commonalities among the parts.

### Bibliography

1. U.S. Department of the Air Force, War Reserve Material. Air Force Regulation 400-24. Washington: Government Printing Office, 1974.
2. -----, Computation of War Reserve Material Requirements for Consumption-Type Items. Air Force Logistics Command Regulation 57-18. Wright-Patterson AFB, Ohio: Headquarters, Air Force Logistics Command, 1978.
3. Rogers, F. Michael, General, USAF. "Readiness: A Logistician's View." Air University Review, Vol. XXVIII, No. 6, pp. 37-41 (September - October 1977).
4. Sherebrooke, Craig C. METRIC: A Multi-Echelon Technique for Recoverable Item Control. Memorandum RM 5078-PR. Santa Monica, California: The Rand Corp., November 1976.
5. U.S. Department of the Air Force. Standard Aerospace Vehicle and Equipment Inventory, Status, and Utilization Reporting. Air Force Regulation 65-110. Washington: Government Printing Office, with change 1 dated 24 May 1978.
6. -----, USAF Supply Manual, AFM 67-1, Vol. I, Part I, Chapter XIV, Washington: Government Printing Office, May 1978.
7. Presutti, V. A. "Spares Options (A Pacer Readiness Study)." Technical Working Paper. Wright-Patterson AFB, Ohio: Air Force Logistics Command (AFLC/XRS), September 1977.
8. Walston, Steve, Captain, USAF. "Proposed BLSS Computation," Unpublished Working Document, Wright-Patterson AFB, Ohio: Headquarters, Air Force Logistics Command, July 1978.
9. Hobbs, Jon R., Lt Col, USAF. Numerous Personal Interviews, Wright-Patterson AFB, Ohio: Air Force Logistics Command, AFLC/XRS, May 1978-November 1978.
10. Eberling, Charles, Major, USAF. "On the Design of Optimum War Readiness Spares Kits." Unpublished research report. Maxwell AFB, Alabama: Air University, April 1978.
11. Brooks, Robin B. S., and John Y. Lee. War Reserve Spares Kits Supplemented by Normal Operating Assets. Santa Monica, California: Rand Corp. Paper 5725, September 1968.

12. Measurements in Military Essentially. The Logistics Management Institute Task 72-3. Washington: The Logistics Management Institute, August 1972.
13. Glazener, Charles U., Captain, USAF, and Captain Alan J. Tinder, USAF. "War Readiness Spares Kit Composition: A Systems Approach." Unpublished Master's Thesis, SLSR 30-76B. Wright-Patterson AFB, Ohio: Air Force Institute of Technology, School of Systems and Logistics, September 1976.
14. Crawford, Gordon B. "The WRSK Evaluation Model." Unpublished research paper. Hickam AFB, Hawaii: Headquarters Pacific Air Forces, August 1977.
15. Brooks, Robin B. S., Colleen A. Gillen, and John. Y Lu. Alternative Measures of Supply Performance: Fills, Backorders, Operational Rate, and NORS. Memorandum RM-6094-PR, Santa Monica, California: The Rand Corp., August 1969 (AD 692703)
16. Muckstadt, John A. "A Model for a Multi-Item, Multi-Echelon, Multi-Indenture Inventory System," Management Science, Vol. 20, No. 4, December, Part I, 1973, pp. 476-487.
17. Fox, Bennett. "Discrete Optimization via Marginal Analysis," Management Science, Vol. 13, No. 3, November 1966, pp. 210-216.
18. Devins, Gerald Lee, Commander, USN, and Jan D. Christensen, Captain, Royal Danish Air Force. "An Application of Static Marginal Analysis in the Generation of a U.S. Navy Repair Material Requirements List," Unpublished Master's Thesis, Monterey, California: Naval Postgraduate School, December 1976.
19. Karr, H. W. and M. A. Geisler, "LOG-X Problem: A Fruitful Application of Static Marginal Analysis," Management Science, July 1956, pp. 313-326.
20. Hillier, Frederick S. and Gerald J. Lieberman. Operations Research, San Francisco, California: Holden-Day Inc., 1974.

## Appendix A

### Computer Algorithm for Constructing BLSS Kits

## Appendix A

### Computer Algorithm for Constructing BLSS Kits

The following algorithm will produce BLSS kits using the present methodology, the marginal aid techniques for  $0 \leq Y \leq 6$ , and the minimization of expected back-orders approach. The algorithm is limited in that it requires a great deal of storage and no more than 30 of each item can be purchased for each kit.

```

PROGRAM BLSS(INPUT,OUTPUT,TAPE1=101B,TAPE5=INPUT,TAPE6=OUTPUT)
DIMENSION SUY(20,50),C(50),PN(50),COST(50),PNF(50),
1Q(50),SUMB(20,50),
2P(1000),SUMM(20,50),QPAV(50)
DOUBLE PRECISION DEMM,OJ,JJC,JQUO,D-,CP,DBL,DEMR,
1SUMR,RODR,RTS,DD,G,DEM,FACT,FACT1,SUM1,SUM2,SUM3,SUME,SUMP,DPLG
DIMENSION ITITLE(6)
INTEGER S,DPA,OSTP,OSTW,9RCDP,BRCOM,PN,PNF,Q,QPAV,DRCTF,DRCT,SN
EXTERNAL FACT,INITIAL,KEE<IT
CALL INITIAL
L=20
KY=6
LK=L

```

C  
C  
C  
C

# READING BUDGET

```

READ(5,110) Y,R
FORMAT(I3,F7.0)
ISIZE=M*L
DO 39 I=1,ISIZE
P(I)=0.0
CONTINUE
DO 173 J=1,M
QPAV(J)=0
PN(J)=0.0
C(J)=0.0
COST(J)=0.0
PNF(J)=0.0
Q(J)=0.0
CONTINUE
DO 23 I=1,L
DO 24 J=1,M
SUM(I,J)=0.0
SUMB(I,J)=0.0
SUMM(I,J)=0.0

```

110

39

173



```

122 DO 122 IP=1,S
SUME=SUME+(IP*(((RDDR*DRCT)**IP)*(DEXP(-RDDR*DRCT)))/FACT(IP))
SUMP=SUMP+(((RDDR*DRCT)**IP)*(DEXP(-RDDR*DRCT)))/FACT(IP)
CONTINUE
GO TO 188
187 SUMP=.0D+0
188 DEMR=RDDR*DRCT
SUMR=S*SUMP
DD=(DEMR-SUMR-S+SUMR)/RDM2
G=(OSTW+DD)*(.1D+1-RTS)+(RTS*BRCOW)
408
C
C
C
COMPUTING THE RLSS KIT
SLW=ODPW*BRRW*BRCDW*QPA+(ODPW*OSTW*ODRW*QPA)
SFW=SLW+SORT(3.0*SLW)
BLSN=SFW-SF
BLS=BLSN+.5
NBLS=FIX(BLS)
PNF(J)=PN(J)
Q(J)=NBLS
COST(J)=NBLS*C(J)
C
C
C
COMPUTING PROBABILITIES FOR MARGINAL AID
BACKORDERS PROBABILITIES
DEMH=G*DEM
DO 2 K=1,L
SUM1=.0D+0
LL=SN+K
IF(LL.GT.150) GO TO 89
DO 1 I=1,LL
KN=LL-I
IF(KN.EQ..0D+0) GO TO 48
SUM1=SUM1+((DEMH**KN)*(DEXP(-DEMH)))/FACT(KN)
502
1
CONTINUE

```

```

48      SUM2=DEXP(-DEMM)
        SUM1=SUM1+SUM2
        SUM3=((DEMM**LL)*(DEXP(-DEMM)))/FACT(LL)
        QU0=SUM3/SJM1
        DQU0=(.1D+1+QU0)
        DL=OLOG(DQU0)
        CP=C(J)
        DBL=DL/CP
        SUM(K,J)=DBL
        DJ=(.1D+1-SUM1)/CP
        SUMR(K,J)=DJ
        GO TO 2
89      SUM(K,J)=.0D+0
        SUMR(K,J)=.0D+0
2       CONTINUE
10      CONTINUE
        KONT=M
        ITITLE(1)=104THE PRESEN
        ITITLE(2)=104T BLSS COM
        ITITLE(3)=104PUTATIONAL
        ITITLE(4)=104 METHOD.
        ITITLE(5)=0
        CALL KEEPKIT(PNF,Q,COST,KONT,ITITLE)
        SV=100000.00
        DO 317 IH=1,M
        IF(C(IH).GE.SV) GO TO 317
        SV=C(IH)
        IHV=IH
317     CONTINUE
        PRINT(5,100)
        PRINT(6,221)
221     FORMAT(34HTHE RLSS KIT AT PRESENT
        SUB=0.0
        DO 222 JB=1,M
        PRINT(6,223) PNF(JB),Q(JB),COST(JB)
        SUB=SUB+COST(JB)

```

```

223 FORMAT(20X,I13,10X,I3,10X,=20.2)
222 CONTINUE
316 PRINT(5,315) SUP
C   FORMAT(10X,"THE COST OF THE BLS IS ",F20.2)
C   MARGINAL AID PER DOLLAR INVESTED
C
DO 6 KO=1,KY
IKIMBON=0
DO 99 I=1,ISI7E
P(I)=0.0
CONTINUE
DO 209 I=1,M
PNF(I)=0.0
Q(I)=0.0
COST(I)=0.0
CONTINUE
KIMB=0
KYY=KO-1
DO 19 JK=1,M
KJ=(QPAV(JK)*KYY)
IF(KO.GT.1) GO TO 119
KJ=KO-1
119 II=L-KJ
IF(II.GE.1) GO TO 7
DO 219 ML=1,L
SUMH(ML,JK)=0.0
GO TO 19
219 GO TO 19
7 DO 5 KI=1,II
SUMH(KI,JK)=SUM(KI+KJ,JK)
5 CONTINUE
IKL=II+1
IF(IKL.GT.L) GO TO 19
DO 205 JKL=IKL,L
SUMH(JKL,JK)=0.0
205 CONTINUE

```

19	CONTINUE BSUM=0.0 DO94 KOUNT=1,M KKONT=KOUNT I=1 SU=SUMY(1,1) JJ=1 DO 14 J=1,M IF(SUM(I,J).LE.SU) GO TO 14 SU=SUMY(I,J) JJ=J
123	
14	CONTINUE KIMB=KIMB+1 P(KIMB)=SUM(1,JJ) BSUM=BSUM+C(JJ) IF(BSUM.GT.B) GO TO 107 DO 33 KIJ=1,M IF(PNF(KIJ).EQ.PN(JJ)) GO TO 108 CONTINUE PNF(KOUNT)=PN(JJ) Q(KOUNT)=1 COST(KOUNT)=C(JJ) IBSUM=BSUM*100 IB=8*100 IF(IBSUM.EQ.IB) GO TO 318 GO TO 109
33	
108	Q(KIJ)=Q(KIJ)+1 COST(KIJ)=COST(KIJ)+C(JJ) IBSUM=BSUM*100 IB=9*100 IF(IBSUM.EQ.IB) GO TO 318 GO TO 109
107	BSUM=BSUM-C(JJ) P(KIMB)=P(KIMB)+1 DO 207 IL=1,LK SUMM(IL,JJ)=0.0
207	

```

109      LZ=L-1
      DO 93 IL=1,L7
93        SUMM(IL,JJ)=SUMM(IL+1,JJ)
          SUMM(L,JJ)=0.0
320        BDIFF=B-BSUM
          IF(BDIFF.LT.SV) GO TO 318
          IF(KIMB.EQ.ISIZE) GO TO 23
          IF(PNF(KOUNT).EQ.0) GO TO 123
94        CONTINUE
          GO TO 29
212        BSUM=BSUM+C(JJ)
          KIMB=KIMB+1
          IF(KIMB.GT.(L*M)) GO TO 318
          P(KIMB)=JJ/100.
          DO 214 MONT=1,M
          IF(PNF(MONT).EQ.PN(JJ)) GO TO 215
214        CONTINUE
          PNF(KKONT)=PN(JJ)
          Q(KKONT)=1
          COST(KKONT)=C(JJ)
          KKONT=KKONT+1
          GO TO 29
215        Q(MONT)=Q(MONT)+1
          COST(MONT)=COST(MONT)+C(JJ)
29        BDIFF=B-BSUM
          IF(IKIMBON.EQ.0) PRINT*, "R1F= ",BDIFF,"KIMB =",KIMB,"KKONT =",
1KKONT
          IKIMBON=1
          DO 213 JZ=1,M
          JJ=JZ
          IF(C(JZ).LE.BDIFF) GO TO 212
          CONTINUE
213        PRINT(6,100)
318        FORMAT(1H1)
100        PRINT(5,180) KY
180        FORMAT(20X,"NUMBER DOWNED AIRCRAFT IS ",I4/)

```

```

140 PRINT(6,140)
    FORMAT(20X,"PART NUMBER",11X,"QUANTITY",20X,"COST")
    KONT=KKONT-1
    DO 15 NN=1,KONT
        PRINT(5,150)PNF(NN),Q(NN),COST(NN)
        FORMAT(19X,113,11X,16,11X,20.2)
    CONTINUE
150 PRINT(5,150) RSUM
155 FORMAT(/20X,"THE MONEY SPENT WAS ",F20.2)
160 DO 116 JM=1,M
    DO 117 IM=1,L
117 SUMM(IM,JM)=0.0
116 CONTINUE
    ITITLE(1)=104THE NEW
    ITITLE(2)=104KIT COMPUT
    ITITLE(3)=104HED WITH DO
    ITITLE(4)=104HWNED A/C =
    ITITLE(5)=KYV
    CALL KEEPKIT(PNF,Q,COST,KONT,ITITLE)
    CONTINUE

6
C
C
C
C
C
BACKORDERS BUYING ROUTINE

J0=0
DO 97 I=1,ISIZE
    P(I)=0.0
    CONTINUE
97 SV=100000.00
    DO 324 IH=1,M
        IF(C(IH).GE.SV) GO TO 324
        SV=C(IH)
        IHV=IH
    CONTINUE
324 DO 224 J=1,M
    PNF(J)=0

```

224	Q(J)=0 COST(J)=0.0 CONTINUE KIM=0 BSUM=0.0 DO 95 K=1,M KKONT=K I=1 SU=SUMB(1,1) JJ=1 DO 96 J=1,M IF(SUMB(I,J).LE.SU) GO TO 35 SU=SUMB(I,J) JJ=J CONTINUE BSUM=BSUM+C(JJ) JO=JO+1 P(JO)=SUMB(1,JJ) KIM=KIM+1 IF(BSUM.GT.B) GO TO 103 DO 37 KIJ=1,M IF(PNF(KIJ).EQ.PN(JJ)) GO TO 111 CONTINUE PNF(K)=PN(JJ) Q(K)=1 COST(K)=C(JJ) IBSUM=BSUM*100 IB=B*100 IF(IBSUM.EQ.IB) GO TO 329 GO TO 112 Q(KIJ)=Q(KIJ)+1 COST(KIJ)=COST(KIJ)+C(JJ) IBSUM=BSUM*100 IB=B*100 IF(IBSUM.EQ.IB) GO TO 329 GO TO 112
121	
96	
37	
111	

```

103      BSUM=BSUM-C(JJ)
        P(J0)=P(J0)+1
        DO 308 IL=1,LK
          SUM9(IL,JJ)=0.0
          LHM=L-1
        DO 113 IL=1,LHM
          SUM9(IL,JJ)=SUM8(IL+1,JJ)
          SUM8(L,JJ)=0.0
          BDIFF=B-BSUM
          IF(BDIFF.LT.SV) GO TO 329
          IF(KIM.EQ.ISIZE) GO TO 26
          IF(PNF(K).EQ.0) GO TO 121
          CONTINUE
          GO TO 26
        BSUM=BSUM+C(JJ)
        DO 311 MONT=1,M
          IF(PNF(MONT).EQ.PN(JJ)) GO TO 312
          CONTINUE
          PNF(KKONT)=PN(JJ)
          Q(KKONT)=1
          COST(KKONT)=C(JJ)
          KKONT=KKONT+1
          GO TO 26
        Q(MONT)=Q(MONT)+1
        COST(MONT)=COST(MONT)+C(JJ)
        BDIFF=B-BSJM
        DO 309 JZ=1,M
          IF(C(JZ).LE.9DIFF) GO TO 310
          CONTINUE
          KONT=KKONT-1
          ITITLE(1)=10*THE EXPECT
          ITITLE(2)=10*HED BACKORD
          ITITLE(3)=10*HRS CASE
          ITITLE(4)=10*H
          ITITLE(5)=0
          CALL KEEPKIT(PNF,Q,COST,KONT,ITITLE)

```

```
PRINT (6,100)  
PRINT (6,140)  
DO 22 NN=1,KONT  
PRINT (6,150) PNF(NN),Q(NN),COST(NN)  
CONTINUE  
PRINT (6,160) 9SUM  
STOP "END OF PROGRAM"  
END
```

22

```
DOUBLE PRECISION FUNCTION FACT(I)  
DOUBLE PRECISION FACT1  
FACT1=1  
DO 73 J=1,I  
FACT1=FACT1*J  
CONTINUE  
FACT=FACT1  
RETURN  
END
```

73

SUBROUTINE INITIAL  
REWIND 1  
RETURN  
END

```

SUBROUTINE KEEPKIT(PNF,Q,COST,N,ITITLE)
DIMENSION PNF(1),Q(1),COST(1),ITITLE(6)
ITITLE(6)=N
COST HAS COST COEF. IN A VECTOR AT LEAST N LONG.
PNF AND Q ARE THE SAME AS COST.
N IS NUMBER OF ITEMS IN A KIT.
ITITLE IS A 6 WORD ARRAY WITH THE TITLE IN 1-4,
CASE NUMBERS IN 5, AND THE VALUE OF N IN 6.
1  BUFFER OUT (1,0)(ITITLE(1),ITITLE(5))
   IF(UNIT(1)) 2,9,2
2  BUFFER OUT (1,0)(PNF(1),PNF(N))
   IF(UNIT(1)) 3,9,3
3  BUFFER OUT (1,0)(Q(1),Q(N))
   IF(UNIT(1)) 4,9,4
4  BUFFER OUT (1,0)(COST(1),COST(N))
   IF(UNIT(1)) 5,9,5
9  STOP"ERROR EOF IN BUFFER IN"
5  CONTINUE
   RETURN
   END

```

C  
C  
C  
C  
C  
C  
1  
2  
3  
4  
9  
5

## Appendix B

### Computer Algorithm for Evaluating BLSS Kits

## Appendix B

### Computer Algorithm for Evaluating BLSS Kits

This computer algorithm will read in BLSS kits and then compute the probability of having Y or fewer aircraft grounded for Y between zero and eleven for each kit. The algorithm then subtracts the cumulative probabilities in order to obtain the point probabilities for Y between zero and ten.

```

C      PROGRAM EVAL(INPUT,OUTPUT,TAPE1=101B,TAPE5=INPUT,TAPE6=OUTPUT)
C
C      THIS PROGRAM EVALUATES BLSS <ITS AND PROVIDES PROBABILITIES
C      FOR Y NUMBER OF DOWNED AIRCRAFT.
C
C      INTEGER OSTP,OSTW,QPA,BRCDD,3RCDW,DSL,DRCT,PNF,Q,SN,S
C      DOUBLE PRECISION DEM,RTS,SJME,RDDR,FACT,FACT1,DEMR,SUMR,DD,
C      1G,SUM1,DM,SUM4,SUM,PKOUNT,SJMP
C      DIMENSION SUM(12,50),INSN(50),OSTP(50),OSTW(50),ODPP(50),ODPW(50),
C      1ODRP(50),DDRW(50),BRCDP(50),3RCDW(50),BRRP(50),BRRW(50),C(50),
C      2DSL(50),DRCT(50),PA(50),PV=(50),Q(50),COST(50),PROB(12),QPA(50)
C      DIMENSION ITITLE(6)
C      EXTERNAL FACT
C      L=12
C      KOUNT=1
C
C      READING THE BUDGET AND PART DATA.
C
C      READ(5,110) M,R
C      FORMAT(I3,F7.0)
C      DO 102 I=1,M
C      READ(5,120) (INSN(I),OSTP(I),OSTW(I),ODPP(I),ODPW(I),QPA(I),
C      1ODRP(I),DDRW(I),BRCDP(I),3RCDW(I),BRRP(I),BRRW(I),C(I),DSL(I),
C      2DRCT(I),PA(I))
C      FORMAT(I13,17X,2I3,F5.4,F5.3,I3,2F5.4,2I3,2F6.4/F10.2,I4,I3,F4.2)
C      CONTINUE
C      PRINT(6,171) (DRCT(J),J=1,50)
C      FORMAT(10X,4I10)
C      CALL GETKIT(PNF,Q,COST,KONT,ITITLE)
C      PRINT*,KONT
C      DO 20 J=1,M
C      DO 17 JK=1,KONT
C      IF(INSN(J).EQ.PNF(JK)) GO TO 18
C      JJ=J
C      CONTINUE
C      IQ=0

```

```

18      GO TO 19
      IQ=Q(JK)
      JJ=J
      PRINT*,IQ
C
C      COMPUTING THE STOCK LEVEL.
C
19      SL=ODPP(JJ)*BRRP(JJ)*BRCD*(JJ)*QPA(JJ)+
      1(ODPP(JJ)*OSTP(JJ)*ODRP(JJ)*QPA(JJ))
      PRINT*,JJ
      SF=SL+SQRT(3.0*SL)
      SN=SF+.5
      S=SN+IQ
      PRINT*,S
      SN=2*SN
C
C      DEMAND ON THE SYSTEM.
C
      TORW=ODRW(JJ)+BRRW(JJ)
      DEM=ODPW(JJ)*QPA(JJ)*TORW**A(JJ)
      RTS=BRRW(JJ)/TORW
C
C      COMPUTING THE TIME PERIOD OF INTEREST.
C
      SUME=.00+0
      RDDR=ODRW(JJ)*ONPW(JJ)*QPA(JJ)*PA(JJ)
      DEMR=RDDR*ORCT(JJ)
311    IF(DEMR.GT.225.) GO TO 187
      IF(SN.GT.150) GO TO 804
      IF(SN.EQ.0) GO TO 197
      SUMP=DEXP(-DEMR)
      NDS=SN
      DO 128 IP=1,NDS
      SUME=SUME+(IP*(((DEMR)**IP)*(DEXP(-DEMR))))/FACT(IP)
      SUMP=SUMP+(((DEMR)**IP)*(DEXP(-DEMR)))/FACT(IP)
128    CONTINUE

```

```

804      GO TO 188
        SUMP=.1D+1
        SUME=.1D+1
        GO TO 188
187      SUMP=.0D+0
188      DEMR=RDDR*DRCT(JJ)
        SUMR=SN*SUMP
        DD=(DEMR-SUME-SN+SUMR)/RDDR
        IF(JJ.LT.150)PRINT*,JJ,DD,SUMR,DEMR,SUME,SN,RDDR,S
        G=(OSTW(JJ)+DD)*(.1D+1-RTS)+(RTS*BRJOW(JJ))

308      COMPUTING THE MATRIX OF PROBABILITIES.
        C
        C
        C
        DM=G*DEM
        PRINT*,DM,S
        DO 1 I=1,L
        NI=I-2
        NLIM=S+(NI*OPA(JJ))+1
        IF(NLIM.LT.1) GO TO 98
        SUM1=.0D+0
        IF(NLIM.GT.150) GO TO 99
        IF(DM.GE.225.) GO TO 99
        IF(NLIM.EQ.1) GO TO 2
        DO 3 KI=1,NLIM
        NN=NLIM-KI
        IF(NN.EQ.0) GO TO 2
        SUM1=SUM1+((DM)**NN)*(DEXP(-DM))/FACT(NN)
        CONTINUE
3      SUM4=DEXP(-DM)
2      SUM1=SUM1+SUM4
        SUM(I,J)=SUM1
        GO TO 1
98      SUM(I,J)=.0D+0
        GO TO 1
99      SUM(I,J)=.1D+1
1      CONTINUE

```

```

20      CONTINUE
130     PRINT(6,130)((SUM(I,J),J=1,M),I=1,2)
C      FORMAT(4E25.17)
C
C      MULTIPLYING THE PROBABILITIES TOGETHER,
C
C      DO 5 I=1,L
C      PKOUNT=.1D+1
C      DO 6 J=1,M
C      PKOUNT=PKOUNT*SUM(I,J)
C      CONTINUE
C      PROB(I)=PKOUNT
C      CONTINUE
C      PRINT(6,123)(PROB(K),K=1,L)
C      NDB=L-1
C      DO 91 I=1,NDB
C      PROB(I)=PROB(I+1)-PROB(I)
C      CONTINUE
C      PRINT(5,122) KOUNT
C      FCRMAT(/15X,"THE PROBABILITIES FOR KIT",I3," ARE:")
122     PRINT(6,123) (PROB(K),K=1,NDB)
123     FORMAT(15X,E21.14)
C      DO 30 K=1,M
C      DO 31 N=1,L
C      SUM(N,K)=.0D+0
C      CONTINUE
C      CONTINUE
C      DO 32 K=1,L
C      PROB(K)=0.0
C      KOUNT=KOUNT+1
C      IF(KOUNT.NE.9) GO TO 25
C      STOP
C      END

```

DOUBLE PRECISION FUNCTION FACT(I)  
DOUBLE PRECISION FACT1  
FACT1=1  
DO 73 J=1,I  
FACT1=FACT1\*J  
CONTINUE  
FACT=FACT1  
RETURN  
END

73

```

SUBROUTINE GETKIT(PNF,Q,COST,N,ITITLE)
DIMENSION PNF(1),Q(1),COST(1),ITITLE(6)
BUFFER IN (1,0)(ITITLE(1),ITITLE(5))
IF(UNIT(1)) 2,9,2
N=ITITLE(6)
BUFFER IN (1,0)(PNF(1),PNF(N))
IF(UNIT(1)) 3,9,3
BUFFER IN (1,0)(Q(1),Q(N))
IF(UNIT(1)) 4,9,4
BUFFER IN (1,0)(COST(1),COST(N))
IF(UNIT(1)) 5,9,5
STOP"ERROR EOF IN BUFFER IV"
CONTINUE
RETURN
END

```

1 2 3 4 9 5

Appendix C

BLSS Kit Evaluations

Table III  
Evaluation of Marginal Aid Kits (\$45,000 Kits)

	$P(y^{\leq 0})$	$P(y^{\leq 1})$	$P(y^{\leq 2})$	<u>Probabilities</u>		
				$P(y^{\leq 3})$	$P(y^{\leq 4})$	$P(y^{\leq 5})$
$P(y^{\leq 0})$	.22924E-03	.79181E-04	.22839E-04	.18055E-04	.71355E-05	.80932E-05
$P(y^{\leq 1})$	.64545E-01	.10222	.94529E-01	.88181E-01	.73703E-01	.71539E-01
$P(y^{\leq 2})$	.35819	.52496	.55496	.54869	.53273	.52227
$P(y^{\leq 3})$	.67888	.82116	.85105	.85386	.85215	.84338
$P(y^{\leq 4})$	.86803	.94066	.95460	.95845	.95966	.95892
$P(y^{\leq 5})$	.95139	.98163	.98662	.98887	.98968	.98979
$P(y^{\leq 6})$	.98314	.99459	.99615	.99715	.99747	.99759
$P(y^{\leq 7})$	.99437	.99847	.99892	.99930	.99940	.99945
$P(y^{\leq 8})$	.99817	.99958	.99970	.99983	.99986	.99988
$P(y^{\leq 9})$	.99942	.99989	.99992	.99996	.99997	.99997
$P(y^{\leq 10})$	.99982	.99997	.99998	.99999	.99999	.99999

Table IV  
Evaluation of Expected Backorders  
and Proposed Method

	Expected Backorders (\$45,000 Kit)	Proposed Method (\$80,000 Kit)
	<u>Probabilities</u>	
$P(y \leq 0)$	.18963E-03	.41232E-03
$P(y \leq 1)$	.80547E-01	.10961
$P(y \leq 2)$	.42940	.44703
$P(y \leq 3)$	.74886	.71702
$P(y \leq 4)$	.90833	.86755
$P(y \leq 5)$	.96988	.94138
$P(y \leq 6)$	.99071	.97510
$P(y \leq 7)$	.99725	.98981
$P(y \leq 8)$	.99921	.99599
$P(y \leq 9)$	.99978	.99848
$P(y \leq 10)$	.99994	.99945

Table V  
Evaluation of Marginal Aid Kits  
(\$80,000 Kits)

	$P(y \leq 0)$	$P(y \leq 2)$
$P(y \leq 0)$	.25251E-01	.25837E-02
$P(y \leq 1)$	.37112	.38059
$P(y \leq 2)$	.73817	.83889
$P(y \leq 3)$	.90801	.96371
$P(y \leq 4)$	.97010	.99122
$P(y \leq 5)$	.99076	.99779
$P(y \leq 6)$	.99724	.99945
$P(y \leq 7)$	.99920	.99986
$P(y \leq 8)$	.99977	.99997
$P(y \leq 9)$	.99994	.99999
$P(y \leq 10)$	.99998	.99999

Appendix D

DYNAMO Flow Diagram

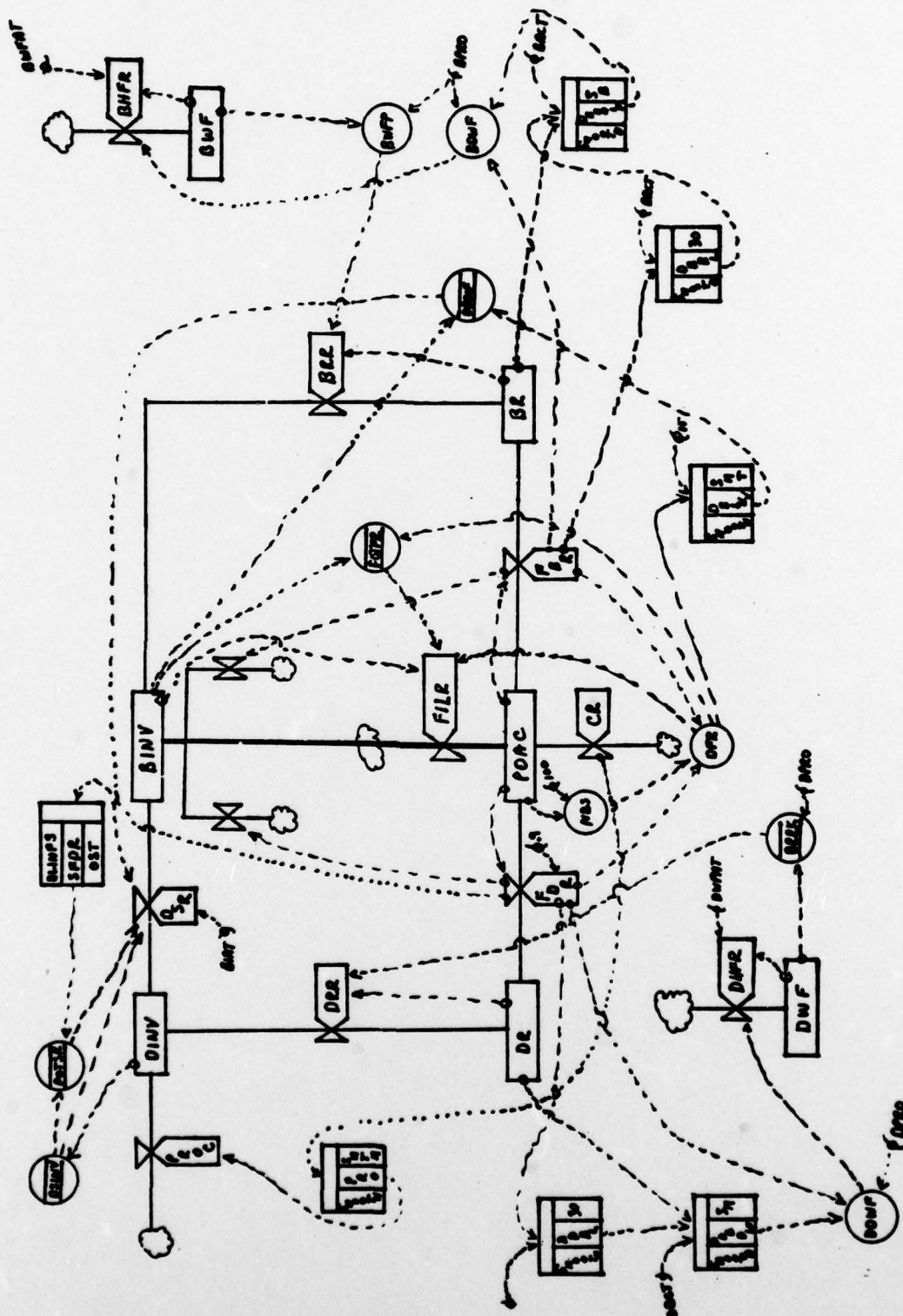


Figure 24. DYNAMO Flow Diagram

## Appendix E

### DYNAMO Computer Algorithm Listing

```

* BLSS MODEL
L PINV.K=PINV.J+DT*(APR.JK+DSR.JK-FILR.JK)
N BINV=DBINV
L DINV.K=DINV.J+DT*(NFR.JK+PROG.JK-DSR.JK)
N DINV=DDIN
A DFR.K=FDR.JK+FR.JK+(NBS.K/BAT)
L DF.K=DR.J+DT*(.9*FDR.JK-DRR.JK)
A DWFF.K=DWF.K*DPROD.K
A DFRK.K=CLIP(DWFF.K,0,DWFF.K,0)
N DF=DDBL
R CA.KL=PC*FDR.JK
A DDINV.K=DDIN*(1+STEP(.5,175))
A PPO.K=SMOOTH(CR.JK,STM)
R PPOC.KL=CLIP(PPO.K,0,PRO.K,0)
A DDINV.K=SMOOTH(FDR.JK+FR.JK,STM)*15
A DDIF.K=DRINV.K-3INV.K
A DDIF.K=CLIP(DDIF.K,0,DDIF.K,0)
A SFRD.K=DLINF3(FDR.JK,OST)
A POTSR.K=MIN(SFDR.K,DSINV.K)
A DR.K=MIN(POTSR.K,(DDIF.K/BAT),DSINV.K)
R DSR.KL=CLIP(DR.K,0,DDIF.K,0)
A DFRR.K=MIN(DRR.K,DR.K)
R DRR.KL=CLIP(DRRR.K,0,DRR.K,0)
A DSINV.K=CLIP(DINV.K,0,DINV.K,0)
L BF.K=RR.J+DT*(FRR.JK-BRR.JK)
N BR=DDBL
A BWFP.K=BWF.K*BPRON.K
A BA.K=MIN(BWFP.K,BR.K)
R BKR.KL=CLIP(BA.K,0,BA.K,0)
A BFRON.K=DPRO
A BPROD.K=BPRD
A DP2DIF.K=MAX(SMOOTH(DBL.K-BR.K,SB)/PRCT,0)
A BOWF.K=(FBR.K+DB3DIF.K)/BPROD.K
R BHRF.KL=(BOWF.K-BWF.K)/BWFAT
L BWF.K=BWF.J+DT*BHRF.JK
N BWF=BWF1

```

```

A DBL.K=SMOOTH(FBR.JK,30)*BRCT
A DBDIF.K=MAX(SMOOTH(DBL.K-DR.<,SM)/DRCT,0)
A DWF.K=(.9*FDR.K+DBDIF.K)/DPRDO.K
A DBL.K=SMOOTH(.9*FDR.JK,30)*DRCT
R DFR.KL=(DDWF.K-DWF.K)/DWFAT
L DWF.K=DWF.J+DT*DFR.JK
N DWF=DWF1
A DRND.K=NOISE()+.5
A AFR.K=-((1/ALPHA)*(LOGN(1-DRND.K))*NPTS
X *(0+STEP(2,40)+STEP(1,20)+STEP(-1,60)+STEP(-.5,80))+1.4*(1+STEP(-1,20)
X )
R FDR.KL=AFR.K*(POAC.K/100)
A BFR.K=NOISE()+.5
A AFR.K=-((1/ALPHA)*(LOGN(1-BFRND.K))* (1-NRTS)
X *(0+STEP(2,40)+STEP(1,20)+STEP(-1,60)+STEP(-.5,80))+.7*(1+STEP(-1,20))
R FFR.KL=AFR.K*(POAC.K/100)
L POAC.K=POAC.J+DT*(FILR.JK-FDR.JK-FBR.JK)
N FCAC=100
A NPS.K=100-POAC.K
R FILR.KL=MIN(DFR.K,RINV.K)
C PC=.1,SMTM=50,BWFAT=10
X ,DWFAT=3,DWF1=.63,RWF1=.35,NRTS=.7,BFRD=2,DPRD=2,
X DFCT=15,BRCT=5,ALPHA=.5
C SMT=15,SM=10,SB=3
C BAT=1
C ODIN=15,BIAT=15,OST=15
PRINT BINV,DINV,DR,BR,DWF,DFR,34F,BHFF,DBINV,DBDIF,
PRINT FBR,FDR,CR,PROC,DSR,BPRON,DPRDO,DRR,BRR,POAC,NBS,POTSR
PRINT DRRK,DBL,DDBL,DDBDIF,DDWF,DSINV,SFDR,FILR,DFR
PRINT DBDIF,DB
PLOT BINV=B,DINV=D,DR=R,BR=B,DRCT=*,BRR=1,FDR=N/DWF=W,BWF=2/NBS=S
SPEC DT=.1,LENGTH=200,PRTPER=0,PLTPER=5
RUN

```

## Appendix F

### Listing of Variable Definitions

## Appendix F

### List of Variables

DRR	Desired Fill Rate
FDR	Fractional Depot Failure Rate
FBR	Fractional Base Failure Rate
POTFR	Potential Fill Rate
FILR	Fill Rate
DSR	Depot Shipping Rate
PC	Percent Condemnations
POTSR	Potential Shipping Rate
DSINV	Depot Shipping Inventory
BINV	Base Inventory
DINV	Depot Inventory
DRR	Depot Repair Rate
DR	Depot Repair
CR	Condemnation Rate
BRR	Base Repair Rate
BR	Base Repair
DWFF	Production by Depot Workforce
DDINV	Desired Depot Inventory
PROC	Procurement
PRO	Smooth of Condemnation Rate
SMTM	Smoothing Time
OST	Order and Ship Time
DWF	Depot Workforce

DPROD	Depot Production
BWF	Base Workforce
BPROD	Base Production
DIDIF	Difference between Desired Base Inventory and Actual Inventory
BWFP	Base Workforce Productivity
BDWF	Base Desired Workforce
BHFR	Base Hire-Fire Rate
BWFAT	Base Workforce Adjustment Time
DBBL	Desired Base Backlog
DHFR	Depot Hire-Fire Rate
DDBL	Desired Depot Backlog
DWF	Depot Workforce
DRND	Depot Random Number
BRND	Base Random Number
POAC	Parts on Aircraft
NBS	Number of Backorders
NRTS	Not Repairable This Station
DRCT	Depot Repair Cycle Time
BRCT	Base Repair Cycle Time
ALPHA	Mean Failure Rate
BIAT	Base Inventory Adjustment Time
BAT	Backorder Adjustment Time

Appendix G

List of Acronyms

### List of Acronyms

A	Difference between required wartime and peace-time assets.
AFIT	Air Force Institute of Technology
AFLC	Air Force Logistics Command
AFLC/ LORRA	Requirements and Analysis Directorate, Headquarters, Air Force Logistics Command
AFLC/ XRS	Management Sciences Directorate, Headquarters Air Force Logistics Command
AF/SA	Air Force Studies and Analysis
BINV	Base Inventory
BLSS	Base Level Self-Sufficiency
BR	Base Repair
BRC	Base Repair Cycle
BRCDP	Base Repair Cycle Days during Peace
BRCT	Base Repair Cycle Time
BRR	Base Repair Rate
BRRP	Base Repair Rate during Peace
BWFAT	Base Workforce Adjustment Time
cdf	Cumulative Density Function
D	Initial Day of war
DD	Depot Delay
DDR	Depot Demand Rate
DDRP	Depot Demand Rate during Peace
DR	Demand Rate
DRCT	Depot Repair Cycle Time
DRR	Depot Repair Rate

DW?AT	Depot Workforce Adjustment Time
EOQ	Economic Order Quantity
FMC	Full Mission Capable
IM	Item Manager
LMI	Logistics Management Institute
LRU	Line Replaceable Unit
MAJCOM	Major Command
METRIC	Multi-Echelon Technique for Recoverable Item Control
MOR	Modified Operational Rate
NMC	Not Mission Capable
NMCB	Not Mission Capable for Both supply and maintenance
NMCM	Not Mission Capable for Maintenance
NMCS	Not Mission Capable for Supply
NORS	Not Operationally Ready for Supply
NRTS	Not Repairable This Station
ODP	One Day flying hour Program
ODPP	One Day flying hour Program during Peace
ODPW	One Day flying hour Program during War
O&ST	Order and Ship Time
O&STQ	Order and Ship Time Quantity
PA	Percent Application
PACAF	Pacific Air Forces
pdf	Probability Density Function
PMC	Partial Mission Capable
QPA	Quantity Per Application
RCQ	Repair Cycle Quantity

RCT	Repair Cycle Time
RTS	Reparable This Station
SLQ	Safety Level Quantity
SM	System Manager
SRU	Shop Replaceable Unit
TDR	Total Demand Rate
WRM	War Reserve Material
WRSK	War Readiness Spares Kit

Vita

Timothy Robert Bridges was born 5 December 1945 in Cincinnati, Ohio. Upon graduation from Western Hills High School in Cincinnati in 1964, he attended the Ohio State University. In 1969, he graduated with a B.S. degree in Industrial Engineering. At the same time, he was commissioned in the U.S. Air Force. In February 1971, he was graduated from undergraduate pilot training and reassigned to Sheppard AFB as an instructor in the German Undergraduate Pilot Training Program. In November 1975, he was reassigned to the Simulator System Program Office, Air Force Systems Command. Then, he attended the Air Force Institute of Technology (June 1977 - December 1978).

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  This thesis develops and demonstrates a method for improving the construction of Base Level Self-Sufficiency (BLSS) kits. This is accomplished by utilizing a cumulative density function describing the probability of Y or fewer downed aircraft. This density function is used in an application of marginal analysis in the construction of demonstration BLSS kits. A comparison is then made between the present, proposed, minimization of		

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20. expected backorders, and the researcher's methodology to determine the best. In all cases, the researchers' method is shown to have a higher probability of Y or fewer grounded aircraft for the particular Y value of interest. The system under which the BLSS must operate is modeled using the DYNAMO system language so as to ascertain the effects upon BLSS performance with parameter changes.

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Joseph T. Hips, Major, USAF  
Director of Information

War Readiness Report Kit (WRSK)  
Base Level Self-Sufficiency (BLSS) Kit

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